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*Western Space Age Industries and Engineering  
Exposition and Conference*

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WESTERN SPACE AGE INDUSTRIES AND ENGINEERING  
EXPOSITION AND CONFERENCE

NASA DAY  
April 27, 1962



General Chairman: Dr. Smith J. DeFrance

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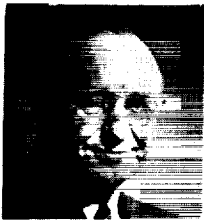
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## BIOGRAPHIES



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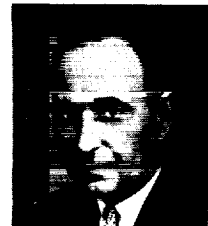
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## NASA PROGRAM

By D. D. Wyatt

### INTRODUCTION

This paper presents a discussion of the NASA program, with the exception of manned space flight which will be covered in the following paper by John H. Disher.

Figure 1 provides an overall glimpse of the way the operating program is divided. The space program can, of course, be subdivided in many ways. The NASA program is organized into four major areas with a supporting activity in tracking and data acquisition.

The first category is basic science conducted in space, in which the upper atmosphere near the earth and on out into the universe are explored. The goal of this area of the program is to acquire as much knowledge as possible about the universe in which we live by conducting fundamental scientific exploration, including the search for life elsewhere in the universe.

The second segment of the program covers those cases in which it is already apparent that space offers advantages as a place to do practical things for our betterment here on earth. This is the area of applications, with projects underway in meteorology and communications.

The third category, manned space flight, will be covered in detail in the following paper. It is in a separate category because manned space flight is not a wholly scientific endeavor, and it would certainly be premature at this point to call it an application.

Underlying all these activities is a fourth major program, the conducting of ground-based research for the advancement of technology, so that the skills and know-how will be available when more ambitious programs are begun in the future. The airplane in the diagram calls attention to the vigorous program of aeronautical research done by NASA. A great deal of ground-based research and development is conducted in the technologies and sciences that permeate the NASA program.

Finally, at the bottom of the chart, underlying all the other activities is the program for tracking and data acquisition using the network of stations scattered around the world for communicating by radio with spacecraft to track them and to acquire data from them.

In this paper the areas of space science, applications, and tracking and data acquisition will be discussed.

## SPACE SCIENCE

The tools employed in the NASA space-science program are in three major groupings: sounding rockets, satellites, and space probes. (See fig. 2.)

Sounding rockets are relatively small rockets fired on vertical or near-vertical trajectories that record information essentially for a moment in time as they rise through the atmosphere and into space and then fall back to earth, telemetering or radioing the information as they travel. A sounding rocket is arbitrarily defined as one that rises no more than 1 earth radius, or about 4,000 miles. If it goes beyond that, it is called a probe. The sounding rocket program is very large and active, involving from 80 to 100 flights a year. These are conducted not only to obtain information, at a point in time, of what is happening near the earth, but also to develop instruments for flight in more elaborate satellite shots in the future.

This country has flown almost 70 earth satellites in various orbital planes and at various degrees of circularity. One of the satellites, Explorer X, flew out to an altitude of about 145,000 miles, more than half the distance to the moon. However, even with such elongated orbits, these are still satellites of the earth, passing around the earth, and are available to provide information for periods of days, weeks, or months.

Finally, there are the space probes. When the sounding rocket goes out beyond 4,000 miles, it is called a geoprobe, or a probe of phenomena associated with the earth. If the craft goes out as far as the moon, it is called a lunar probe. If the spacecraft is simply aimed at the reaches of space, out to the distances of the planets but without any attempt to intercept a planet, it is called an interplanetary probe. One such spacecraft, Pioneer V in 1960, sent scientific information back to earth by radio over a distance of  $22\frac{1}{2}$  million miles. Thus far, this is the long-distance communication record. When the spacecraft is actually aimed at a planet, it is called a planetary probe.

In most cases relatively single-purpose satellites have been flown up to this time in the scientific satellite program of this country. These have not been very heavy. They have tended to be concentrated in a single scientific disciplinary area, such as the study of the very rarefied high-altitude atmosphere or the radiation belts and other energetic particles or the magnetic field, the electrical fields, and so on. Until recently, the weight-lifting capacity of available rockets was quite small.

In March 1962, however, the first of what are called observatory-class satellites was flown. These are somewhat larger and carry a greater variety of experiments than previous satellites. They are called observatories because they carry a number of related experiments not necessarily concentrated in one scientific discipline.

The first one of these is the Orbiting Solar Observatory, abbreviated OSO, which has 13 related experiments (fig. 3). The satellite is stabilized in space so that the upper portion faces the sun at all times. The shining surface consists of solar cells for the conversion of light energy into electricity. The observatory instruments on the upper portion always point at the sun to take long-term measurements of the sun's activity and characteristics. These measurements are much more difficult to obtain from the earth's surface because the radiation from the sun is partially obscured and partially distorted by the atmosphere. The lower part of the satellite is a wheel, having three arms, which revolves in space for stability. There are small gas jets on each of the three arms that are fired to control the orientation of the satellite to keep the upper portion pointed at the sun.

The 13 experiments concentrate on a detailed examination of the sun's surface and its activity. Knowledge of the sun is extremely important in a large number of areas because all life on earth is utterly dependent on the sun's energy and because of the many ways the activity of the sun manifests itself in the lower part of the earth's atmosphere, affects long-distance radio communications, and so on. The OSO weighs 450 pounds and is in a circular orbit at an altitude of something over 300 miles.

In approximately a year, there are plans to fly another kind of observatory, which is called the Orbiting Geophysical Observatory, or OGO. There will be two versions of the OGO. The one illustrated in figure 4 is the Eccentric Geophysical Observatory (EGO). Eccentric means that its orbit is a long ellipse. Its apogee, or the farthest point from the earth, will be about 60,000 miles; the perigee, or lowest point, will be 150 or 200 miles from the earth's surface.

The Great Radiation Belt, sometimes called the Van Allen belt after James A. Van Allen, lies in a region from 600 miles to perhaps 20,000 miles from the earth. This zone, detected by the first U.S. satellites, consists of bands of concentrated energetic particles - protons, electrons, alpha particles, and so forth - mostly coming from the sun, which are trapped in the earth's magnetic field. The EGO is a device that will slice through these fields at periodic intervals, travel on out into free space conditions outside the effective magnetic field of the earth, and then return. A wealth of information is anticipated in many scientific areas, including an examination of the radiation belt itself.

The spacecraft is stabilized so that it is oriented toward the earth, pointing one axis toward the earth all the time. It will be possible to fly about 20 simultaneous experiments. Some of them will continually observe the earth. Others will be pointed out into space. Some experiments will obtain information in the plane of the ecliptic, the plane in which the earth revolves about the sun. Others will measure out into a direction at right angles to the ecliptic plane. Still other experiments will point at the sun, supplementing the measurements of the solar observatory. By making these measurements simultaneously, relationships between the various phenomena may be discovered. Again, this spacecraft is properly called an observatory because it does perform a broad range of functions.

Another version of the OGO is called the Polar Orbiting Geophysical Observatory, or POGO, which will be in a low orbit over the polar regions. Both forms of OGO weigh about 1,000 pounds of which about 150 pounds will consist of experiments.

The most elaborate NASA observatories, which will be flown in about 2 years, are the Orbiting Astronomical Observatories, or OAO (fig. 5). These will be primarily for the purpose of making observations of the universe beyond our solar system. From the earth's surface only visible and infrared light and certain so-called windows in the radio spectrum can be detected. The ultraviolet, X-rays, gamma rays, and large sections of the radio spectrum are largely shielded from observations from earth. Thus, knowledge about the stars and distant regions of the universe is limited. If this kind of observatory is orbited above the earth's atmosphere, at an altitude of 300 or 400 miles, knowledge will be greatly increased. The first set of experiments being planned will be a set of coordinated experiments in the ultraviolet-light region. The astronomers consider this region particularly interesting because newborn stars, those in the early stages of creation, are believed to emit most of their energy in the ultraviolet range.

The OAO will weigh in the range of 3,000 to 3,500 pounds, a payload well within the capacity of the Atlas-Agena launch vehicle. It will carry optical telescopes, eventually up to 36 inches in diameter. The pictures will be recorded and stored on magnetic tape and then retransmitted by radio to the surface of the earth, where the physical look at the heavens will be reconstructed. Like the other observatories, it will have solar panels for converting light into electricity.

It is worth noting that repeated flights of all these observatories are planned. They are so designed that the whole basic spacecraft will not have to be redesigned when experiments are changed. Instead, experiments will be interchanged or new experiments will be inserted - either whole new experiments or range and sensitivity changes on existing experiments - as preliminary information is obtained and more careful

investigations are needed. Consequently, there are plans to employ the same basic spacecraft, launching them at 6-month intervals over the next decade.

These three observatories illustrate the directions and the kinds of scientific measurements that can be obtained with these scientific satellites. To back them up, there will be perhaps 6 to 10 smaller, more specialized satellites flown each year. These will carry the kinds of experiments that either are not compatible when grouped together in an observatory spacecraft or require special orbits, different from those of the observatories.

The next group is space probes. First is the lunar program. The family of Ranger spacecraft is shown in figure 6. Late in 1961, there were two flights of the Ranger A, which was designed for technological proof-testing of the spacecraft itself, although it contained instruments suitable for making measurements of interplanetary space. There were failures of different kinds during the launch of each spacecraft. Consequently, they were never put into the intended highly eccentric trajectories. In both cases, however, the technological test proved fairly satisfactory because the spacecraft did separate and each of the elements of the spacecraft did what was required.

As in the observatories, there is a basic "bus" that contains the power supplies, the telemetry, and other service units. In the diagrams, the solar panels for the conversion of solar energy and a movable antenna that can be pointed back to the earth can be seen. The radio signals must be directed back to the earth on a very narrow beam in order to be received from the distances involved.

One attempt at a lunar impact with Ranger B was made in January 1962. Ranger B is basically the same spacecraft as Ranger A, but the interplanetary instrumentation has been removed and replaced with a ball coated with balsa wood, with a retrorocket attached. The rocket does not show in this illustration because it is underneath. The principle of the Ranger B is to fly on an impact course with the moon. At a distance of a few thousand miles from the moon, the main spacecraft would start taking a series of pictures about every 13 seconds, which can be reconstructed into a television sequence showing the approach to the moon. The main spacecraft approaches the moon at a speed of 6,000 to 7,000 miles per hour, enough to destroy the entire device on impact. At a few score miles above the moon's surface, however, the retrorocket is fired and the balsa-wrapped package is separated and brought to rest in space. The main spacecraft impacts the moon and is destroyed. The package falls with the pull of the moon's gravity, hitting at about 150 miles per hour. The package is designed so that its contents will survive such an impact. In the package is a single-axis seismometer for measuring disturbances in the lunar crust, or "moonquakes." This

kind of information could be transmitted back for about a month after impact. It would give a good deal of information about the internal structure of the moon. In particular, information is desired on whether there is any possibility of live volcanic action and whether the moon has a liquid core or a porous spongy structure all the way through.

The television pictures taken every 13 seconds on approach will provide a fair amount of closeup detail. From the earth's surface, the best telescopes do not enable us to see details less than several thousand feet across. No object smaller than this on the moon's surface can be detected. When men are landed on the moon in later U.S. manned flight programs, a landing gear of some sort must be provided. Obviously, adequate landing gear cannot be designed if detail under 2,000 to 3,000 feet cannot be seen.

Ranger is thus the first step in acquiring some real understanding about the actual measure of the moon's surface. Several more of these Ranger B lunar probes will be flown this year. The next one is scheduled shortly. The first Ranger B did not receive the right launching velocity. It went out a little too fast. The error was too much to be corrected with the small rocket carried to make a course correction, and it missed the moon by about 23,000 miles.

The surface information is so important to future programs that a third version of Ranger, called Ranger C, which will carry more cameras of higher resolution, has been added to the programs. The balsa-covered ball will be replaced to provide for the additional camera and electronic system weight. Pictures will be taken on approach to the lunar surface in order to build up background understanding of its makeup.

NASA has under construction a second generation of lunar spacecraft called Surveyor (fig. 7). Surveyor differs from Ranger in that the whole spacecraft will be slowed enough so that it will land gently on the moon's surface and the entire spacecraft and its instrumentation will survive. The large rocket motor in the diagram will slow it and then the three legs will act as a landing gear. Surveyor is a very complex spacecraft which weighs considerably more than Ranger - more than 2,000 pounds as compared with 750 pounds.

All the instruments on the Surveyor will not be described herein; briefly, there are again solar cells and antennas pointed at the earth and sun. Surveyor will also contain a core-sample driller, similar to the kind used in oil-well drilling, which will take a sample of the first 5 feet of the moon's crust. It will drill down through the crust, pull up the sample, and pass it in front of a spectrographic analyzer. Thus, it will be possible to transmit back to earth the chemical analysis of this first 5 feet of the moon's crust. In addition, the Surveyor will contain scanning television. There will be several television cameras

with rotatable mirrors, making it possible to scan the area around the impact point and obtain a panoramic television view of the vicinity. Some of the television is arranged so that it will be possible to take microscopic photographs of the moon's surface. It also contains radiation detectors and other devices for measuring the moon's atmosphere, if any, at the surface. Most of these detectors are on long-boom arms that extend out beyond the spacecraft after landing. Thus, further detail about the actual physical nature of the lunar landscape, both visually and from the standpoint of scientific analysis, will be obtained. These details will again be obtained at a localized point, near the point of impact.

A number of Surveyor A spacecraft will be landed at different points on the moon's surface, but each one will give only a localized view. In order to obtain overall information, the basic Surveyor has been modified to make a lunar satellite. Surveyor B, in orbit around the moon with television reconnaissance cameras, will take pictures of the entire lunar surface. This photography will probably not be of sufficient accuracy of orientation to allow the drawing of literal maps, as does aerial photography. These reconnaissance photographs can, however, be made into mosaic maps of the moon's surface. Then, an attempt will be made to correlate the detailed measurements taken at specific sites with the general observations. The combined information will provide detail of importance in the steps to select suitable landing sites.

Conceptually study is being made of the stage beyond this in the lunar program. Some of the larger launch vehicles being developed for the manned space flight program will make it possible to place spacecraft weighing up to 20,000 pounds or more on the moon's surface. The possible ways in which these vehicles can be used are being studied. Perhaps they will be multipurpose vehicles with mobility after arrival on the moon's surface. Perhaps they can land the main spacecraft and some subpart might move around the moon's surface. They might be employed essentially as supply vehicles or logistic carriers in support of man. Or they might carry separate scientific payloads so that the unmanned exploration of the moon can be extended. This latter concept comes under the general name Prospector.

Figure 8 shows not only how the capacity of scientific experiments increases, but also an increase in the regions of the moon that can be explored. Ranger has several restrictions. It must come in at right angles to the moon's surface - that is, straight down. It has to be within sight of the tracking station at Goldstone, California, which will command its actions and receive television transmissions in the later phases. Hence, Rangers must land in the area shown in the figure.

Surveyor A will land a larger spacecraft on the moon and will have more onboard power. Consequently, it can be landed at an angle of  $45^{\circ}$

as well as at right angles. Surveyor can land on about 45 percent of the moon's surface, as shown on the left side of the figure. The Prospector would be big enough so that it could presumably go into an orbit about the moon and then select a landing site any place on the moon's surface, front or back. Thus, through this family growth in the spacecraft, increases can be made not only in the amount of scientific data to be obtained but also in the area of the moon to be explored.

The next phase of the program is planetary exploration. Figure 9 shows schematically the fact that only two planets - Venus, in toward the sun, and Mars, farther from the sun than the earth - are susceptible to practical scientific exploration from earth at the present time and probably within this decade. By the end of this decade, however, with the development of larger launch vehicles, it will probably be worthwhile to send payloads in toward Mercury and perhaps even closer to the sun, and out toward Jupiter. However, at the present time, the size of payloads that could be propelled to those distances would not warrant the attempt.

The family of probes designed to investigate the planets is known as the Mariner family, Mariner R and Mariner B. At a later stage an advanced spacecraft called Voyager will be used. At the bottom of the figure are listed the objectives to be sought in space between the earth and the planets and around the planets themselves.

The Mariner R (fig. 10), the first version of the Mariner spacecraft, will be launched for the first time in August 1962. Two launches are scheduled. The energy considerations are such that it is practical to launch a spacecraft toward Venus only every 19 months, when Venus and the earth are in favorable opposition, so that after about 3 months of transit time, the spacecraft will intercept Venus in its orbit. Mars can be intercepted only about every 25 months. Thus, the planetary exploration program comes at discrete times.

In a period of about a month in the late summer of 1962, two attempts are planned to pass a spacecraft in the vicinity of Venus, in what is called a flyby. It is hoped that the Mariner will come about as close to Venus as the Ranger did to the moon in January 1962, within about 20,000 miles.

The basic Mariner spacecraft developed out of the Ranger. Here, again, the antenna can be seen pointing back to earth while the solar cells face the sun (fig. 10). The interplanetary instrumentation is carried on the upper section and the power supplies and telemetry are on the main bus section. Plans call for this spacecraft to be used again in 1964 when another opportunity comes to fly by Venus.

The next version is Mariner B (fig. 11), which starts from the same basic family, although it is somewhat different in appearance. The basic power package is present, but there are more solar cells, since it is designed to fly toward Mars, where the sunlight is not so bright. The major difference in the Mariner B, however, is that there is a section which can be separated and deployed as the planet is approached. The section can go through the planetary atmosphere and radio information about the nature of the Martian atmosphere back to the main spacecraft as the craft flies by the planet. It is planned to fire this detachable pod at Mars in 1964 and at both Mars and Venus on successive planetary opportunities.

When the larger launch vehicles of the manned program become available, spacecraft that are considerably larger than the Mariner series can be launched. As in Prospector, the weight will be about 20,000 pounds or more. Such a weight-lifting capacity affords the opportunity to go first into an actual orbit about the planet with the main spacecraft and take television reconnaissance photographs of the surface. An unmanned capsule like that in Mercury or Discoverer, which will land on the planet's surface, might be detached later in Project Voyager. (See fig. 12.)

Figure 13 summarizes the differences between the Mariner R, the Mariner B, and Voyager spacecraft. Mariner R and Mariner B will fly by the planets at some close-miss distance. Mariner R will simply scan the surface as it goes by - with radiometers for the most part - and acquire data during its flyby. Mariner B will, in addition, have a detachable pod that goes in to the planetary surface and obtains a preliminary indication of the planetary surface composition. Finally, the Voyager will actually go into a satellite orbit around the planet and then will detach the pod that could obtain data right down to the surface.

This program is about what can be foreseen of a decade of planetary exploration. Perhaps by the end of the decade it may be possible to send crude spacecraft of the Mariner R type out as far as Jupiter and in as far as Mercury.

## APPLICATIONS

The next area of the space program is that of employing space for practical useful applications. The discussion involves two major areas, meteorology and communications.

In the meteorology program, four of the Tiros satellites have been successfully launched. These are research and development vehicles to develop the technology for acquiring certain kinds of weather information from above the atmosphere, which is possible from the path of a

satellite. In this highly successful program about 75,000 photographs of clouds have been taken, transmitted back to the earth, and are being used for weather research and in daily weather forecasting. There are certain limitations to the Tiros satellite, however. It is space oriented, which means that it points constantly in one direction in space. As a result, the cameras onboard look at the earth during only part of the revolution. During the rest of the time, the cameras look out into space and obtain no useful information.

In order to overcome this difficulty, a spacecraft known as Nimbus is being designed; it is earth stabilized, meaning that its cameras will point at the earth all the time by stabilizing and moving the spacecraft around its own axis. The second difficulty - and this is not fundamental in the program - is that Tiros has been flown on fairly low inclined orbits. The coverage has only been between the latitudes of  $50^{\circ}$  north and south. The Nimbus will fly a nearly polar retrograde orbit, which will cover the entire earth and will pass any spot on earth about once in every 12 hours.

It is believed that a spacecraft like Nimbus will be the basis of an operational meteorological system. In the future, the need will probably arise for another kind of satellite, flying out to distances at which it will revolve about the earth once every 24 hours. If such a satellite, called the Aeros, is traveling from west to east over the equator, it will appear to be stationary when viewed from the earth, about 22,000 miles above the earth's surface. Figure 14 shows the three types of meteorological satellites.

Figure 15 shows the details of the Tiros satellite. The instrumentation consists primarily of television cameras that take low-resolution pictures which are, however, satisfactory from the meteorological viewpoint and infrared detectors that scan to measure the balance of radiation into the earth and out from the earth. The radiation information enables us to draw infrared maps of the temperature zones on the earth. This kind of meteorological information is very difficult to obtain from any earth-based system. It may in the long run prove very valuable in the study of how weather generates. Such understanding may make long-range weather forecasting possible. The rest of the spacecraft consists of equipment needed to record, store, and, on radio command, transmit to earth the data that are acquired. The entire outer surface of Tiros is covered with solar cells for electrical energy.

An example of what can be done with an instrument even so elementary and, in a sense, unprogramed, as Tiros is shown in figure 16. These are composite photographs taken on one day, September 11, 1961, with Tiros. On this day seven storms were detected, including five hurricanes in the Atlantic area. This was the day when hurricane Carla crossed the Texas coast, and there were two typhoons in the Far East. Hurricane Esther

was discovered on September 11 by Tiros. It was so far out in the Atlantic that Tiros was the only means of detecting it for 2 days, after which it had moved close enough to the shore for weather observation planes to go out and locate it and positively identify it as a hurricane.

Figure 17 shows a little more detail. The meteorologist takes data from Tiros, makes weather maps, and feeds the maps into a facsimile transmitter, which sends them to all weather data users. The chart concentrates on the region showing hurricane Carla. On the same day, hurricane Debbie went up toward the coast and Esther approached. The data from Tiros have given us a great deal of faith and assurance that here is a tool that can be employed to improve weather forecasting greatly.

The Nimbus flight program is a joint NASA Weather Bureau effort. It is hoped that in a few years it will lead to operational satellites as part of the day-to-day weather system. Such weather information is not only of value to the United States, but also to the whole world. Details of the Nimbus satellite are given in figure 18. Nimbus contains essentially the same kind of instruments - television cameras and infrared scanning - as Tiros, but it differs in the requirement that it point to the earth at all times. At the same time, the solar cells have to face the sun as the spacecraft revolves around the earth. The combination of requirements leads to a fairly sophisticated stabilization problem. The upper section senses and maintains the stability. The electronics working section is in the lower portion. Since the satellite will go around the earth once every 90 minutes, the lower section will have to turn around the horizontal axis every 90 minutes while the solar cells remain facing the sun.

Nimbus will be a large step forward from Tiros, since it will pass over the same point on the earth every 12 hours and will provide continuous photographic coverage of the entire earth. It still suffers limitations, however, as can be seen by examining a plot of the size of storms against their typical lifetimes in figure 19. The large cyclonic systems that comprise the weather across the United States, or hurricanes that are one particular violent form of weather, are large enough and of long-enough duration that observations of them every 12 hours are sufficient to provide a knowledge of how the weather is developing. However, with the more intense, localized storms, observation every 12 hours is insufficient. Thunderstorm complexes, although very large, do not last long. The thunderstorm cells, and the most destructive of all, the tornadoes, have relatively short lives. Thus, there is need of a supplementary system to Nimbus, which will be able to study storm systems over a longer period of time. Nimbus, on its pass over an area, might detect an incipient or existing weather situation that is likely to develop into a severe storm. Then, the Aeros would focus on it and

study it as it builds up. If a tornado were located, it could be observed almost continually and eventually predictions of locations where tornadoes may strike might be possible.

At an altitude of 22,300 miles over the equator, the Aeros (fig. 20) would revolve every 24 hours and thus would remain over a given spot on the equator. If three Aeros satellites could be placed around the earth in proper locations they would be able to see most of the earth's surface. They could not see the polar regions too clearly, of course. At present, work is being done only on some of the components, such as the cameras. The idea is that the Aeros would be a spacecraft either with a variable-focus camera or with two cameras; in the latter case, one camera would take a fairly wide look at the earth's surface and the other, on command, would examine a more localized zone containing an area of special weather interest. It is felt that a satellite like Aeros may complement the Nimbus satellites in a total worldwide meteorological observation system.

Another area of great practical interest is communications. Figure 21 illustrates the different projects contained within the NASA program of communications satellites.

Figure 22 shows drawings of Echo I and Echo II. Echo I was launched during August 1960 and is still aloft. It has begun to lose its shape but is still visible, although not so bright as when it was originally launched. It is called a passive communications satellite because it simply acts as a reflector. It does not play any active part in the communication process.

Being planned is the Rebound project, in which more than one Echo satellite would be launched with a single launching vehicle. There are also the active communications satellites, so called because they have electronic systems and are in fact retransmitting stations. These projects are Relay and Syncom in the wholly NASA program; Telstar, a satellite financed by American Telephone and Telegraph Company complements the NASA series.

Echo I is 100 feet in diameter. Its skin is thin, composed of 0.0005-inch Mylar plastic, with vapor-deposited aluminum coating inside and out. When fully inflated, its surface is relatively rough, as shown in figure 20. For Echo II, the construction was changed and even thinner Mylar was employed. Then a laminate of aluminum was placed inside and out in order to increase the structural rigidity, which will allow an increase in inflation pressure. Echo II will have a much smoother surface after inflation. It will also be a little larger, with a diameter of 135 feet instead of 100 feet; thus, it can be flown at a slightly higher altitude, which will permit transmission between stations a little farther apart.

Figure 23 shows an inflation test on Echo II in a balloon hangar and gives an indication of its size. The illustration shows how smooth the surface is after inflation.

There is a considerable lack of definitive information as to whether a passive-type communications system really has a potential commercial future. The balloon does not contain any instrumentation except a simple tracking beacon radio transmitter. It encounters radio signals from the ground and simply reflects them back to the ground. By its nature, the passive satellite requires a rather high transmission power at one station and a very sensitive receiver at another station. The satellite must be tracked simultaneously from the transmitting and receiving stations. The passive satellite has the obvious advantage that there are no airborne electronics to fail.

In addition to work with the passive spheres, NASA is expending a good deal of effort in the development of active satellite systems. These satellites have flight electronics and provide a relay station in the sky. With an active repeater satellite, a relatively weak signal can be taken from one point on earth and received on the satellite, amplified, and retransmitted to another point on earth. The second receiver need not be too sensitive. Hence, the ground installation requirements for the active system are considerably reduced in comparison with those for the passive system. The disadvantage, of course, is that the satellite can always fail. Tubes or transistors can fail, or the power supply can weaken. The name Project Relay has been given to the first medium-altitude satellite being flown by NASA.

Figure 24 is a schematic diagram of the active repeater satellite. It is entirely covered with solar cells to provide electrical energy. In addition to performing communications functions, this satellite is also an exploratory device to learn causes of failure in components. In order to provide such information, there are devices to obtain an overall measure of its capability to communicate back to a ground point and instrumented components and subsystems that will tell in detail how they are performing and how they are degenerating with time. The principal cause of failure seems to be the impact of the energetic particles in space with the solid-state components, actually knocking atoms out of position in these crystals and destroying their effectiveness. For example, the solar cells degenerate so that the power output goes down over a period of time. Transistors, diodes, and so forth, become inoperative. Instrumentation onboard the Relay may indicate what is happening to these components. In addition, in order to relate this effect to events occurring outside, instruments will be stored within the spacecraft to detect and measure the energetic particle field through which the spacecraft is passing. Thus, it is hoped that both cause and effect will be determined, in detail and grossly.

The active satellite has a promising future in its great capacity to expand communications channels. In the undersea cables and commercial radio links with Europe, there are the equivalent of about 100 voice channels; that is, about 100 conversations with Europe can be in progress simultaneously. One television transmission requires the equivalent of about 1,000 voice channels. Thus, even if all the present links could be combined into one package, only about one-tenth the capacity now required to transmit television to Europe could be obtained.

A relatively small active repeater spacecraft such as Relay can be built to accommodate up to four television channels or about 4,000 voice channels in a single spacecraft. It greatly broadens the horizon of intercontinental communications. Economically, active satellites will probably prove much cheaper than the equivalent in cables, microwave stations, and so on, as requirements for these communications channels become evident.

Project Relay is planned for medium altitudes. At these altitudes, there must be 40 or 50 satellites aloft so that in a random fashion one would always be visible between any given transmitting and receiving station. Just as with the Aeros meteorological satellite, if these satellites go out far enough, to a distance of 22,300 miles, they would be stationary over a point on the equator, and would always be visible between points about a third of the earth's surface apart.

The 22,300-mile 24-hour satellite is called synchronous, because its orbit is synchronized with the rotation of the earth. The synchronous communications satellite is abbreviated with the project name Syncom. The Syncom must be lighter and smaller to enable it to be launched to that altitude; thus, it will not have as much capacity as the Relay. The initial version will have a relatively limited voice channel capacity, but it will explore the problems at the synchronous altitude.

The situation involves engineering trade-offs. At low altitude, the electronic components suffer damage because of the radiation belt. At 22,300 miles, the spacecraft, although substantially out of the belt, must be stabilized in some fashion and the antenna must be pointed toward the earth. Otherwise, the requirements for airborne power to get the signal back to the earth will run too high. So the stabilization problem must be balanced against the electronic problem.

The Telstar satellite is similar in principle to Relay, but it will differ in detail. It will also work in the medium altitude range.

## TRACKING AND DATA ACQUISITION

In this section is a brief discussion of what is required in the way of ground installations to back up the NASA program by tracking satellites and spacecraft.

Figure 25 shows the network of ground stations established for Project Mercury which was employed in tracking Astronaut John Glenn on his flight around the earth. There are 18 stations in the Mercury network, scattered along the orbit that was flown. Five of these stations are operated directly by NASA. The others are operated by the Department of Defense at its existing sites or supported by the Department in some fashion. This is the kind of network needed when it is necessary to know every instant where an object is and where it would be if it had to be called out of orbit. Specialized tracking devices are required.

The unmanned satellites are not recoverable. There is no intention to call them out of orbit. Thus, it is not necessary to know as rapidly where they are. Information can be accumulated on them over a period of hours and then their ephemeris or orbital path calculated. On the other hand, broader coverage over the earth is needed, since unmanned satellites fly in orbits of varying inclination. Consequently, there is a different kind of network, shown in figure 26. This network has a different kind of ground instrumentation, in which there is both tracking and data acquisition from the unmanned satellites. This network will have to be expanded in some degree for the more advanced observatories which were previously mentioned.

One specialized kind of tracking used for scientific satellites is the optical method. Other tracking devices are electronic - they are essentially radio receivers sufficiently sophisticated to measure the direction from which a signal comes. Measuring radio impulses is fairly accurate, but not precise. For precision, special cameras, known as Baker-Nunn cameras, are employed to photograph the satellite path against a star background. This can be done, of course, only at twilight or early in the morning, when the earth is still dark but the sun is illuminating the satellite out in space. Since the positions of the stars are known with great accuracy, the path and location of the satellite can be deduced with a high degree of accuracy. The stations must be located in areas that are relatively free of clouds most of the time. Desert areas are preferred. The white dots in figure 27 show the locations of these optical tracking stations, operated for NASA by the Smithsonian Astrophysical Observatory. The inserts show, left, a Baker-Nunn camera and, right, a representation of the path of a satellite through the star field.

For tracking lunar and deep-space probes, different equipment is required, because the spacecraft are so far out and the signals are so weak that very sensitive receivers must be used. At present, in use are big dish antennas (fig. 28), which are 85 feet in diameter, about the equivalent of an eight- or nine-story building. The antenna is free to move on all axes and point at any part of the sky. There are three antennas: Goldstone, California; Woomera, Australia; and near Johannesburg, South Africa. They are about 120° apart around the earth. Thus, after a spacecraft gets a few thousand miles out into space it can be seen by one station or another as the earth rotates under it.

Space is rather remote - essentially all intelligence must be obtained by radio. This will continue to be the case until the capacity to place man in space to explore it is improved. Even then, communication with man will be by radio. Thus, these facilities will continue to be required.

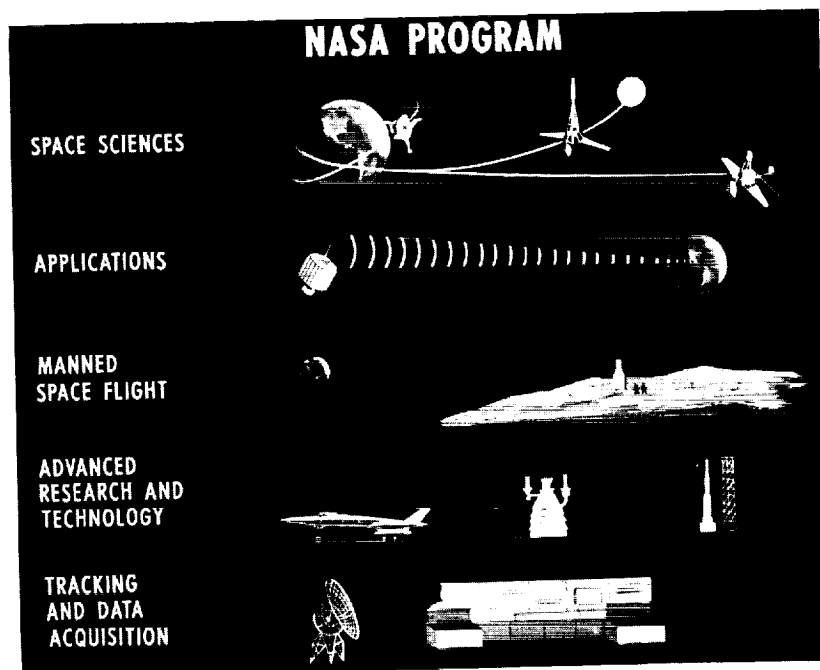


Figure 1

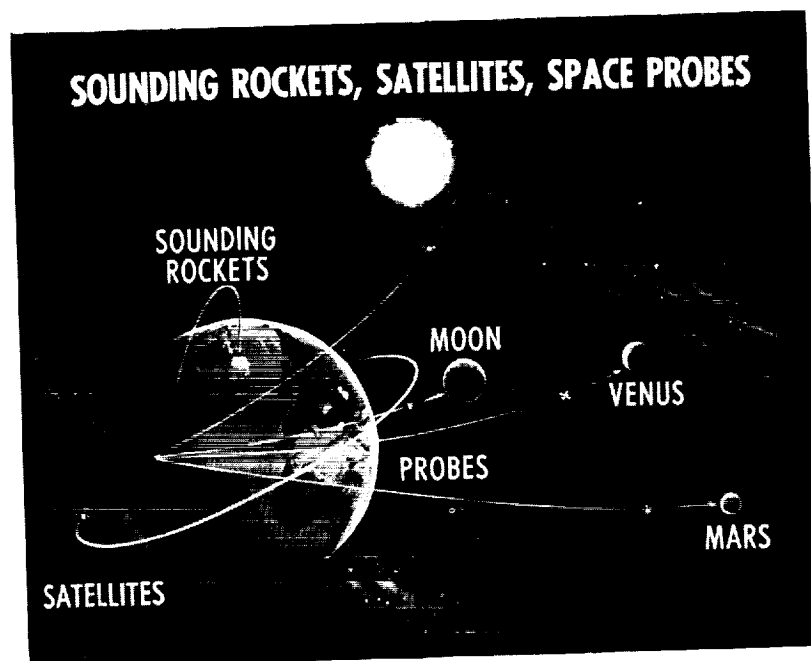


Figure 2

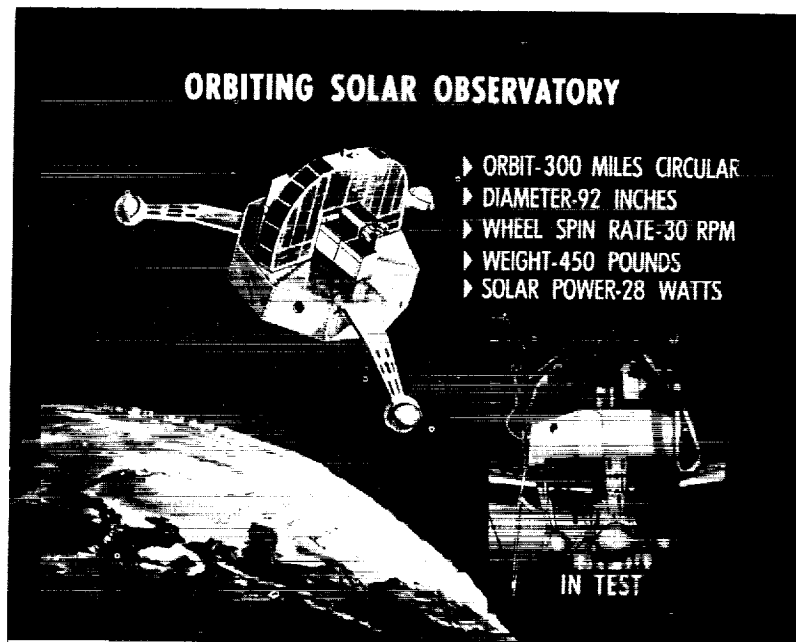


Figure 3

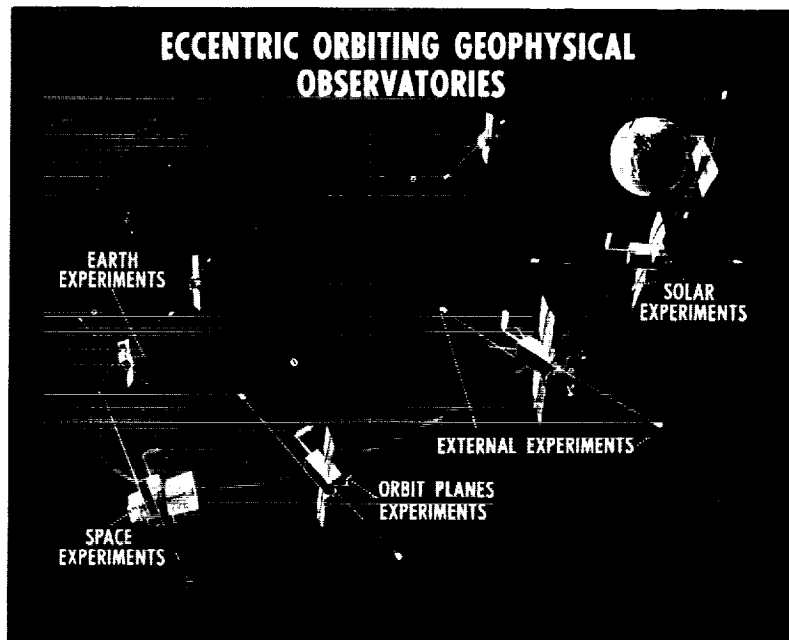


Figure 4



Figure 5

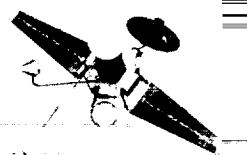
## LUNAR PROGRAM-SPACECRAFT

RANGER A



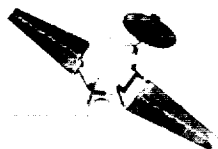
SPACECRAFT TEST  
INTERPLANETARY  
MEASUREMENTS

RANGER B



• LUNAR IMPACT  
TV RECONNAISSANCE  
LANDING CAPSULE

RANGER C



LUNAR IMPACT  
HIGH-RESOLUTION TV

S 67 255

Figure 6



Figure 7

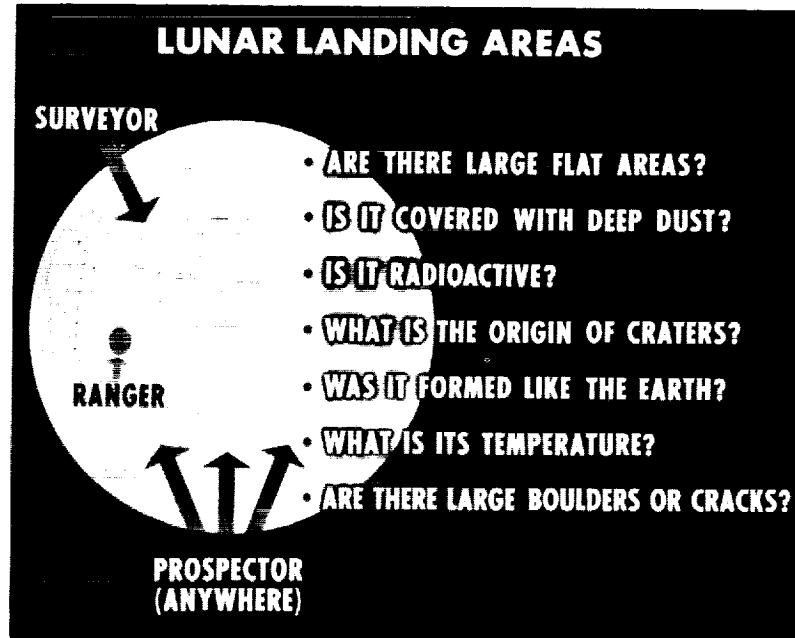


Figure 8

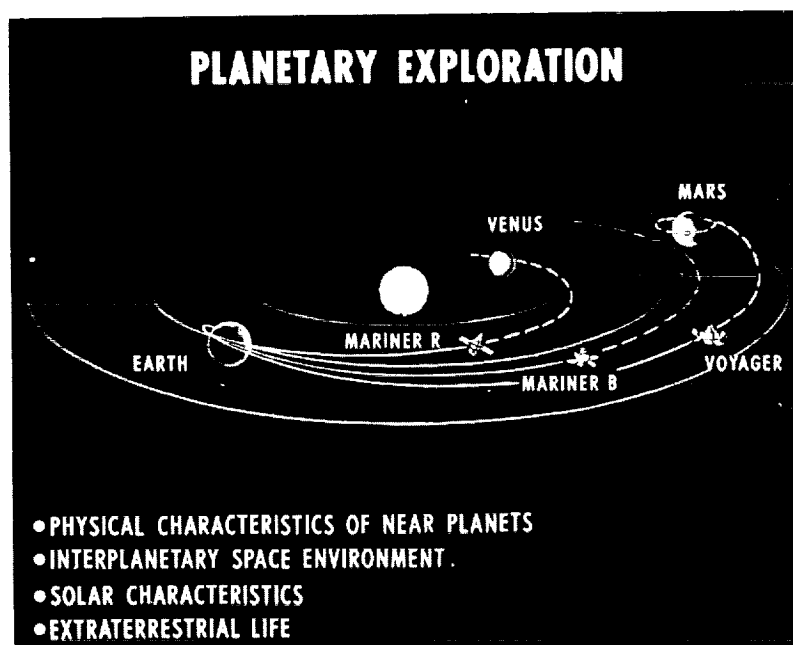


Figure 9

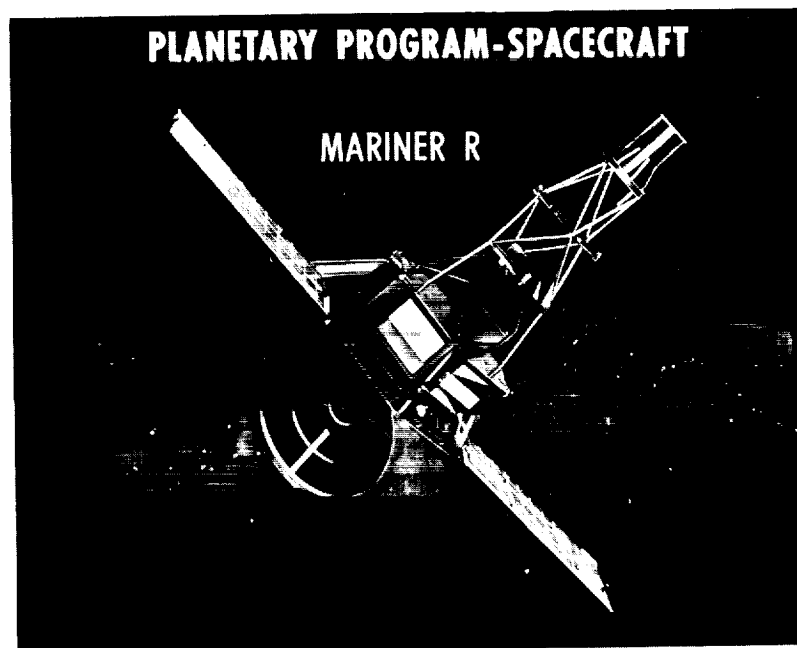


Figure 10

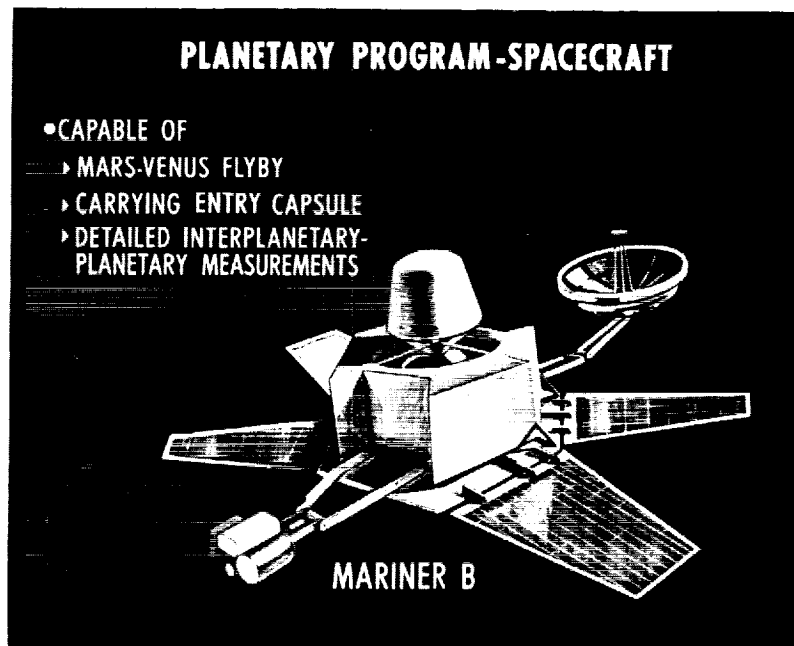


Figure 11

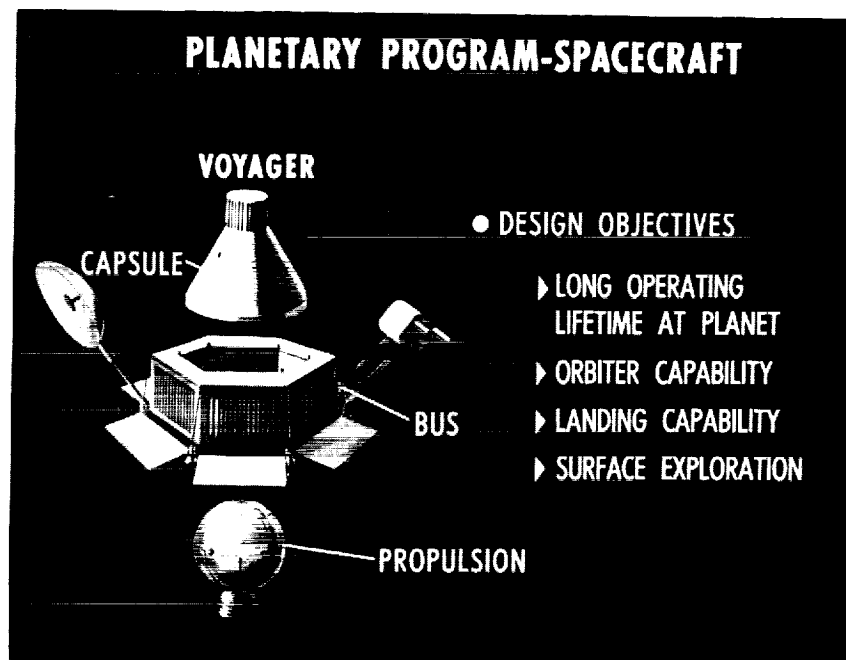


Figure 12

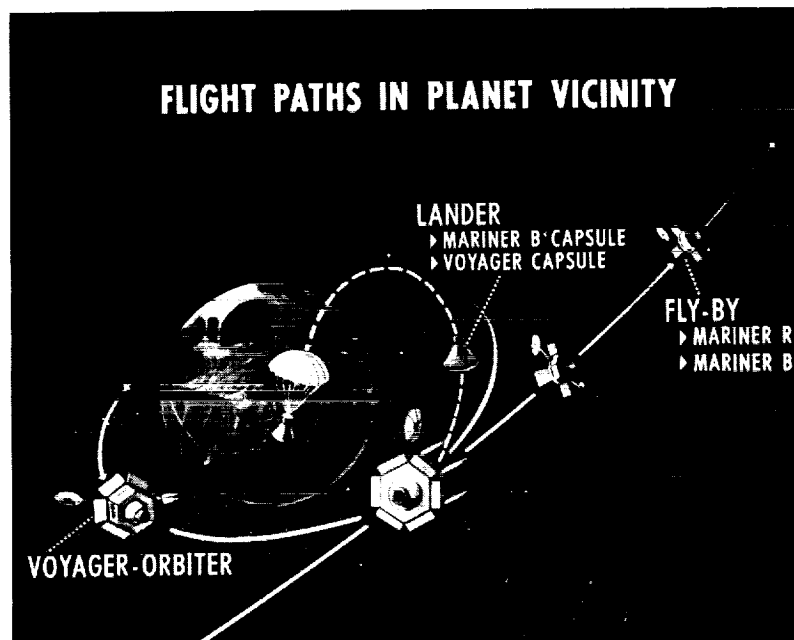


Figure 13

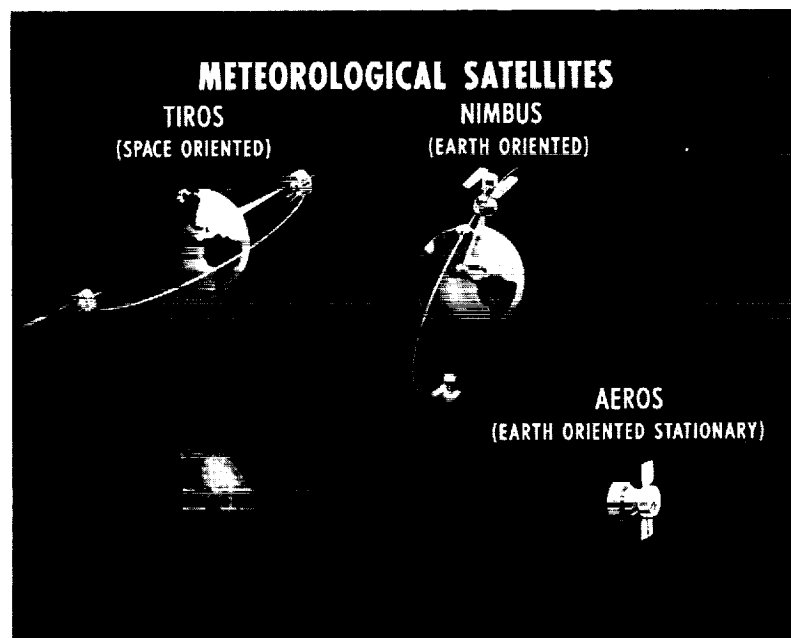


Figure 14

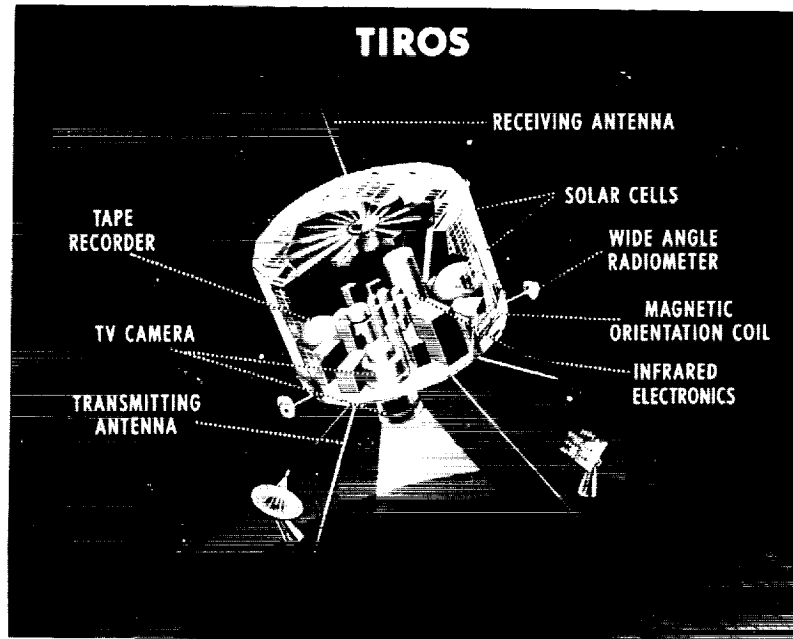


Figure 15



Figure 16

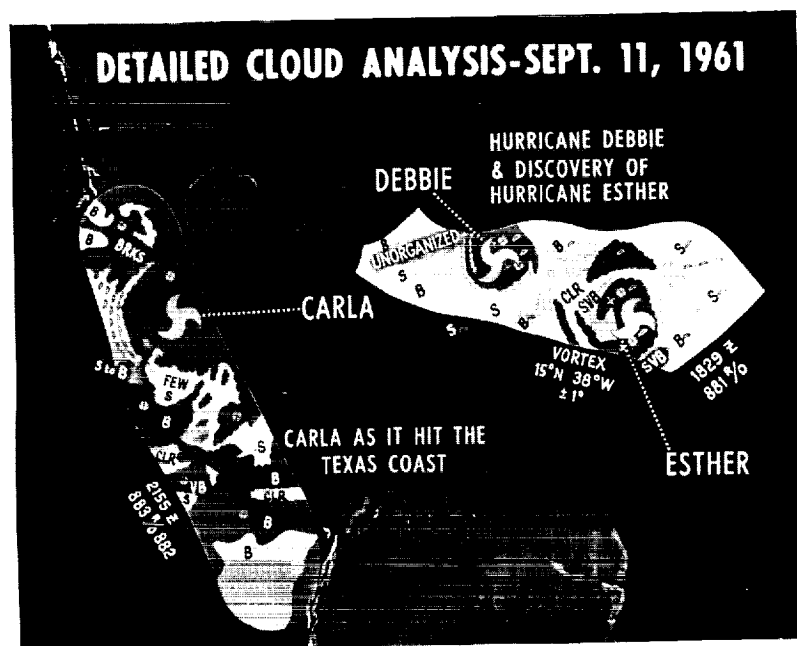


Figure 17

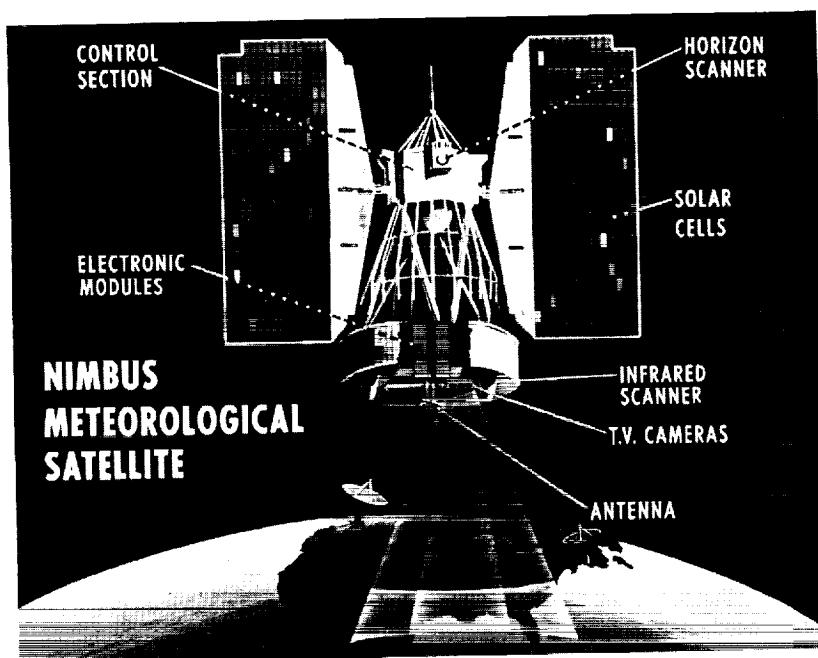


Figure 18

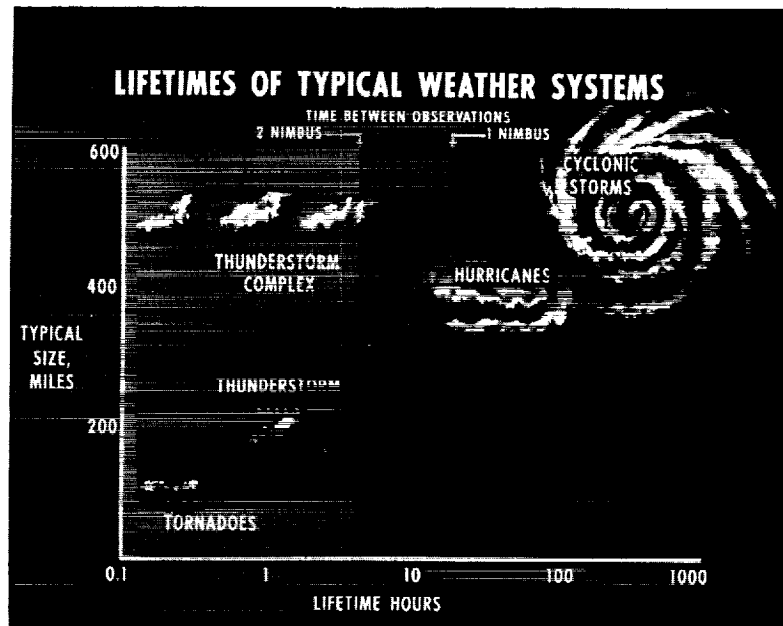


Figure 19

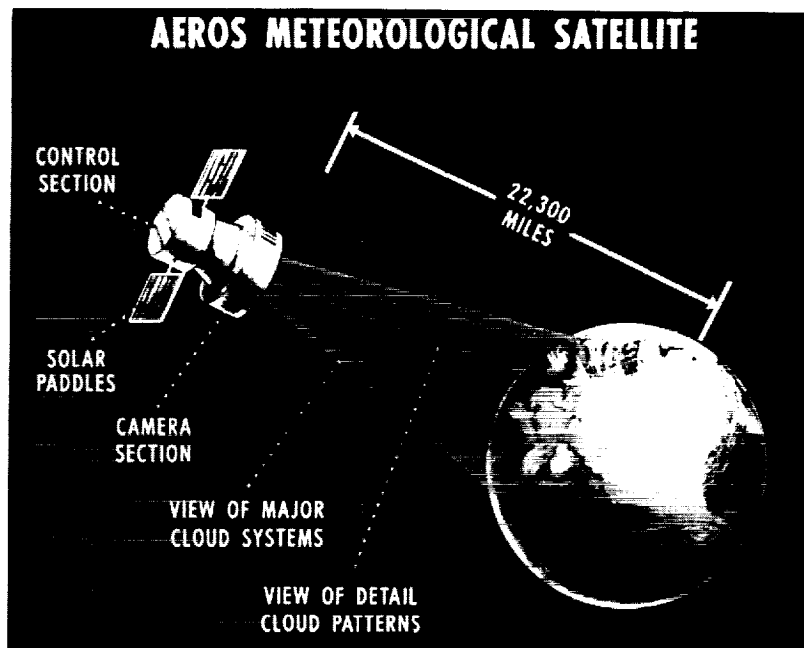


Figure 20

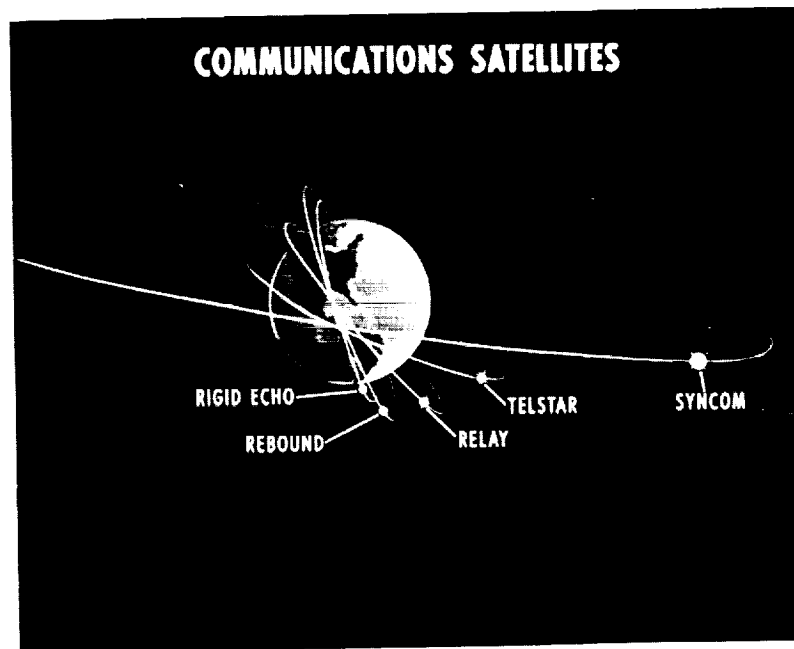


Figure 21

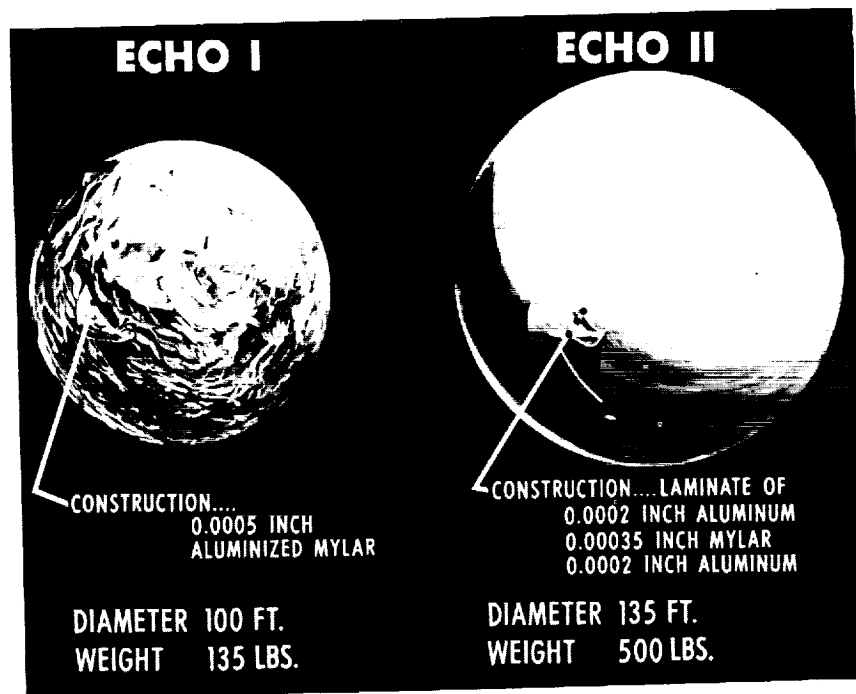


Figure 22

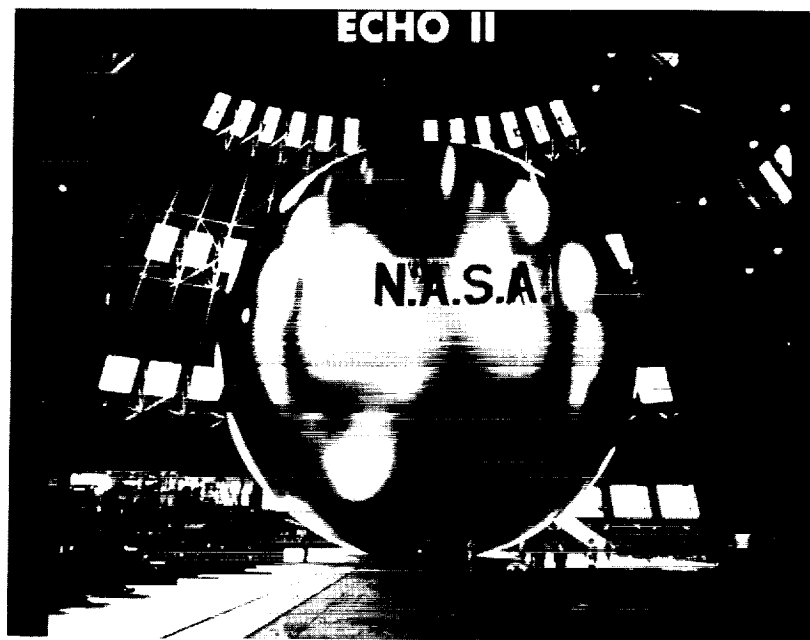


Figure 23

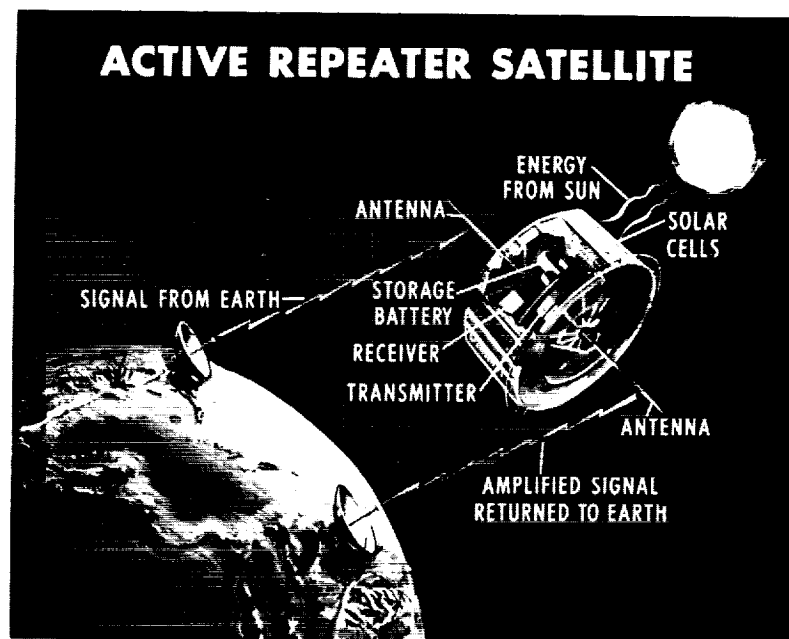


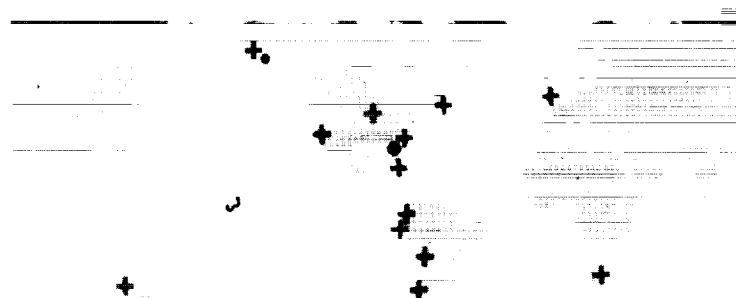
Figure 24

## MERCURY TRACKING DATA ACQUISITION NET



Figure 25

## EARTH SATELLITE INSTRUMENTATION



### STATION LOCATIONS

COLLEGE, ALASKA	ANTOFAGASTA, CHILE	EAST GRAND FORKS, MINNESOTA
FT. MYERS, FLORIDA	WINKFIELD, ENGLAND	BLOSSOM POINT, MARYLAND
QUITO, ECUADOR	ROSMAN, N. CAROLINA	ST. JOHNS, NEWFOUNDLAND
LIMA, PERU	GOLDSTONE, CALIFORNIA	JOHANNESBURG,
SANTIAGO, CHILE	WOOMERA, AUSTRALIA	REPUBLIC OF SOUTH AFRICA

Figure 26

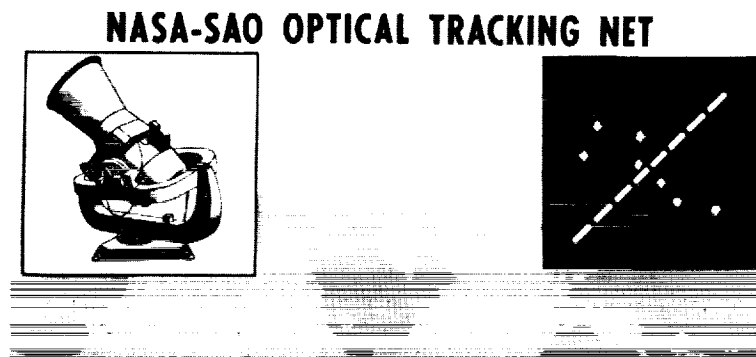


Figure 27

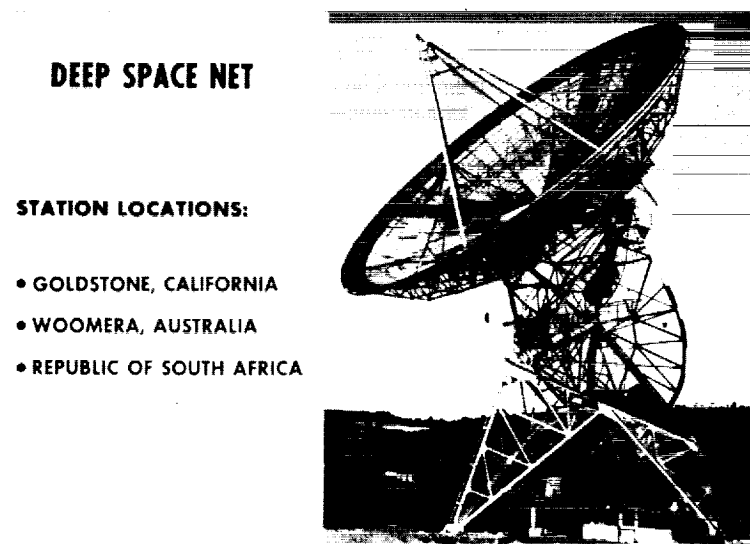


Figure 28

## MANNED SPACE FLIGHT

By John H. Disher

## INTRODUCTION

The Manned Space Flight program within NASA includes all those major program elements required to carry out the manned space flight missions. Included are the development of the spacecraft, the development of the launch vehicles, the provision of the necessary facilities, the selection and training of the flight crews, and the conduct of the missions. In this paper, a description of the overall manned missions that are presently in the NASA program and the spacecraft and launch vehicle developments that are required will be presented.

The NASA Manned Space Flight program, as shown in figure 1, consists of four major program areas. First is the basic Mercury three-orbit missions. Following completion of the basic Mercury three-orbit missions, the Mercury spacecraft will be suitably altered to allow flight durations of up to 1 day. These are called 1-day manned missions. The third project area is called Project Gemini, which extends the capability for orbital flight to two men for periods up to approximately 10 days and provides initial capability for development of rendezvous techniques. The Gemini spacecraft makes maximum use of Mercury technology, in that it is the same shape, uses similar systems, and is built by the same manufacturer. The fourth major project area is designated Project Apollo, which has as its objective the accomplishment of a manned lunar landing and return mission. Preliminary to that mission, and a part of Project Apollo, are earth orbital and circumlunar missions. Before examining each of these projects in detail, it is desirable to consider the time phasing or scheduling of the various projects, as shown in figure 2.

With regard to Project Mercury, the initial objective was accomplished on February 20, 1962, when Astronaut John Glenn successfully circled the earth three times. During the remainder of 1962, the potential exists for as many as three or four additional three-orbit flights with the Mercury spacecraft. These additional flights will amplify and expand the data obtained during John Glenn's flight. The next Mercury flight is scheduled for May 1962 with Astronaut Scott Carpenter on-board. Toward the end of 1962, the first flight of a modified Mercury spacecraft with 1-day-in-orbit capability will be made. Present plans provide for up to four of these flights during the 1963 time period. These flights will provide the United States with the earliest possible exposure of man to weightlessness for periods of the order of 24 hours. These data are extremely important because of the extensive effects they could have on future spacecraft design and astronaut training

procedures. The Russian Titov is reported to have experienced nausea and air sickness after approximately 6 hours in orbit, just beyond the duration of John Glenn's flight. It is extremely important that it be determined as early as possible whether this illness that Titov experienced was peculiar to him and whether the ability to withstand weightlessness may vary from individual to individual or with training and experience. John Glenn stated that he observed no effects whatsoever, other than that weightlessness was a very pleasant state.

The Gemini project is scheduled for first flights in late 1963 and will continue during the next 2-year period. The earth orbital phase of Apollo will start first flights in late 1964 and extend through the 1966 time period. The circumlunar phase of Apollo is scheduled for the 1967-68 time period. The lunar landing mission is scheduled for the latter years of the decade, either by rendezvous or direct flight. (The differences in these techniques will be discussed subsequently.)

### PROJECT MERCURY

With the completion of the first orbital manned flight of Mercury, it is possible to examine the complete flight development program that was required for this initial manned venture into space. Shown in figure 3 is a summary of results for the complete Mercury flight program. A total of 19 flights were carried out in the Mercury development and qualification program. In 16 of those flights, the mission objectives were accomplished; a total of 16 successful flights were required to develop the spacecraft and associated equipment necessary for the accomplishment of the mission. This total program included: unmanned ballistic flights on the Atlas; unmanned ballistic flights on the Little Joe and Redstone vehicles; animal flights on the Little Joe and Redstone; manned ballistic flights on the Redstone, which of course included the flights of Astronauts Alan Shepard and Virgil Grissom; and, finally, unmanned, animal, and manned orbital flights on the Atlas. The lessons learned from Mercury have been many and extensive. Each of the flights illustrated here was an essential part of an overall development program. Each of the flights contributed hard-won knowledge which could be obtained in no other way than actual doing. Thus, a major contribution of Mercury has been the experience gained in the design, development, and operation of the first manned spacecraft system in the free world.

Highlights of the Mercury flight program are shown in figures 4 to 7: Shepard's ballistic flight on May 5, 1961; Grissom's flight on July 21, 1961; the primate Enos' orbital flight on November 29, 1961; and John Glenn's flight on February 20, 1962.

Proceeding now to the manned 1-day mission, the objectives, figure 8, are to attain an early extension of man's experience under weightless conditions up to 1 day and to determine effects of prolonged weightlessness and of g-stresses after weightlessness at as early a time period as possible. In order to carry out these objectives, the spacecraft will be the Mercury spacecraft with minimum modification. The spacecraft alterations consist primarily of providing additional cooling water, breathing oxygen, hydrogen peroxide for attitude control, and electrical power to the system. In order to allow the weight necessary for these items, certain equipment items will be removed from the spacecraft. Notable among these is the pilot's periscope.

## PROJECT GEMINI

In earlier discussions of Project Apollo, alternative methods by which the mission could be accomplished, either by direct flight on a large rocket vehicle or by rendezvous using several smaller launch vehicles, were mentioned. The rendezvous technique offers the possibility of earlier mission accomplishment. Therefore, the rendezvous technique must be investigated and developed at the earliest possible date. The objectives of Gemini are given in figure 9. Project Gemini has as one of its major objectives initial experiments into the development of suitable rendezvous techniques. The Gemini spacecraft is illustrated in figure 10. The Gemini spacecraft is approximately a foot larger in diameter than the Mercury spacecraft. In terms of volume, this added foot means an increase in useful volume of over 50 percent so that an additional crew member and the required supplies for the extended duration and rendezvous missions can be carried within the spacecraft. The craft is identical in shape to the Mercury craft so that all the benefits of the Mercury development experience can be applied. In addition, many of the Project Mercury subsystems will be used in altered form for the Gemini craft. Many of the lessons of design and maintenance capability that have been derived from Project Mercury will be applied to the Gemini detailed design. The Gemini spacecraft will weigh approximately 6,000 pounds as compared with the approximately 3,000 pounds for Mercury. The added weight of Gemini, of course, requires a larger launch vehicle than does Mercury, and the launch vehicle that has been selected is the Titan II, illustrated in figure 11. For the rendezvous development missions of Gemini, a second launch vehicle, the Atlas-Agena B, will be used to launch a rendezvous target into orbit. The rendezvous development exercises will be carried out as shown in figure 12. Shown in this sequence is first the launching into orbit of the Atlas-Agena B rendezvous target. After attaining a successful orbit, the ephemeris of that orbit will be determined by ground tracking and data acquisition. The launch of the manned spacecraft will then take

place on the Titan II. The Gemini spacecraft will be launched into as near a coincident orbit with that of the Agena as possible. Both accuracy of injection and time of launch are important variables in this rendezvous problem. When it is considered that the target is moving at a velocity of 5 miles a second, the precision of launch time requirement becomes evident. If desired launch time were missed by 10 seconds, the intercept would be off by 50 miles, even if the guidance were perfect. With both the manned Gemini craft and the Agena target successfully in orbit, the manned craft will maneuver the Agena B target toward itself to effect the rendezvous. The large amounts of maneuvering will be provided by the Agena B target upon command from the manned spacecraft. When the two vehicles are in proximity, the manned spacecraft will maneuver into a docking situation with the target, and an actual mechanical linkage of the two units will be made, as illustrated in the lower right-hand part of figure 12. However, whether it is the target that is doing the maneuvering or the Gemini spacecraft, the man in the Gemini spacecraft will be providing the command and maneuvering intelligence to bring the two pieces of the system together. The gross velocity corrections are provided by the Agena with its large amount of propulsion onboard, and the small amounts of maneuvering are provided by the Gemini spacecraft. After the linking of the two units, the two-unit assembly then can go on to perform additional maneuvers in space for experimental and developmental purposes.

#### PROJECT APOLLO

The objective of Project Apollo may be stated rather simply: to accomplish at the earliest practicable date manned lunar landing and return.

As in Project Mercury, however, a very extensive development and qualification program is required before this end objective can be achieved. Thus, as illustrated in figure 13, Project Apollo really consists of three major missions. First, the Apollo craft will be developed, proved, and qualified in earth-orbit missions. Next, after successfully completing the orbital phase of the program, the craft will be projected into space to the vicinity of the moon, will circle the moon, and return to earth without landing on the moon. Insofar as proving the capability for man to operate the spacecraft in cislunar space and for the spacecraft to negotiate reentry into the earth's atmosphere, the circumlunar mission provides the full capability that will be required for later lunar landing. Thus, the circumlunar mission is an essential prerequisite in a logical development toward the Apollo lunar-landing mission. For the actual lunar-landing mission, the flight of the space ship to the moon and return from the vicinity of the moon to earth is similar to that for the circumlunar mission. However, for the landing mission,

the spacecraft must, of course, be lowered gently to the lunar surface and subsequently take off again. The spacecraft is illustrated schematically in figure 14 in its full lunar-landing configuration. For the earth orbit and circumlunar missions, only the upper parts of the spacecraft from the service module on up are carried. Although the complete Apollo spacecraft as shown lands on the surface of the moon, only the command and the service modules leave the surface of the moon, and only the command module containing the crew returns to earth. The command module contains the crew quarters and their life-support equipment and accompanying supplies. It provides the capability for reentry at 25,000 miles per hour and provides the capability for aerodynamic lift to provide landing point control during reentry. The service module contains stores and supplies which are not essential during reentry and which are not adaptable to inflight maintenance and therefore can be made external to the living quarters of the crew. Behind these supplies is the abort and lunar take-off propulsion which provides the impulse required to leave the surface of the moon after having landed there, or which, in an emergency, provides the abort or return-home capability for the craft. The command and service modules together weigh approximately 50,000 pounds, when configured for the lunar-landing mission. For earth-orbit missions, the propellant tanks of the service module need be only partially full, so that the payload weight of the spacecraft can be compatible with the smaller launch vehicles available for the earth-orbit mission. When the lunar-landing module is added for the lunar-landing mission, the total spacecraft weight is approximately 150,000 pounds. The lunar-landing module would typically consist of a hydrogen-oxygen propulsion stage with suitable landing gear and sensing equipment to allow a gentle landing on the surface of the moon.

Now consider the several means by which the lunar landing can be carried out. The two means that we have talked about are by direct flight or by rendezvous. These two techniques are illustrated in figure 15. In the left part of this figure, the direct flight technique is illustrated. In this mission mode, the complete spacecraft is injected on a trajectory toward the moon. This means that a single launch vehicle capable of projecting approximately 75 tons to escape velocity must be provided. A launch vehicle having this capability has been designated Nova and is presently in the study stage. In the right-hand part of the figure is illustrated the earth rendezvous technique, one of several possible rendezvous approaches to the mission. In this mode, several flights of a smaller launch vehicle are used. With the Saturn C-5, two launches are used. In the first launch, an orbital departure propulsion stage is placed into orbit. Then with the second flight, the complete spacecraft is injected into an earth orbital trajectory much the same as will be done in Project Gemini. These two components, the Apollo spacecraft and the orbital departure stage, are then joined in orbit. The orbital departure stage then accelerates the spacecraft to escape velocity on a trajectory similar to that for the Nova.

By means of rendezvous, it may be possible to accomplish the mission with two flights of a small launch vehicle as compared with a single flight of a large launch vehicle. The advantage of this technique is that the small launch vehicle can be available earlier than the large launch vehicle and thereby affords the possibility of carrying out the mission earlier.

The several launch vehicles required for the Apollo program are illustrated in figure 16. In the left part of the figure is illustrated the initial Apollo launch vehicle, the Saturn C-1. This vehicle has a 20,000-pound payload capability in a 300-mile earth orbit and will be the launch vehicle for the earth orbital missions for the Apollo program. For the circumlunar mission, a single flight of the advanced Saturn vehicle is required. A single flight of this launch vehicle has the capability of injecting the command and loaded service modules on a trajectory toward the moon. For the lunar landing by means of rendezvous, two of these advanced Saturn vehicles will be required and are illustrated in the center of the figure. Finally, for the direct approach, a single flight of the large vehicle, designated Nova, is required.

Shown in figure 17 is the first launch of a Saturn vehicle which took place on October 27, 1961. In that flight, which had only a first stage with dummy upper stages, flight objectives were completely attained, and the flight was a complete success.

Look now at the various pieces of hardware required to accomplish the manned programs discussed and consider their present procurement status. In figure 18 are illustrated the major pieces of hardware. Starting at the upper part of the figure, the Mercury and Gemini spacecraft are presently under contract with the McDonnell Aircraft Corporation. The Apollo command and service modules are under contract with North American Aviation, Space and Information Systems Division, in Downey, California. The Apollo lunar-landing module is the major part of the Apollo spacecraft that is not yet under contract. As for the launch vehicles, the Atlas and Atlas-Agena B are well into their flight programs; the Saturn C-1: the first stage is being built by the Chrysler Corporation and the second stage is being built by the Douglas Aircraft Corporation. With regard to the advanced Saturn or C-5 version, the first stage is under contract with the Boeing Airplane Company and will be constructed at the Michoud Plant near New Orleans, Louisiana. The second stage of the advanced Saturn is under contract with the North American Aviation Corporation. The third stage of the advanced Saturn is nearly identical to the second stage for the Saturn C-1 and is being built by the Douglas Aircraft Corporation. That same stage, built by Douglas, forms the third stage for the Nova vehicle. The first two stages of the Nova vehicle are presently under study, and a competition is presently under way for industrial support to that study effort.

Turning to the organization for carrying out this tremendous program, the overall program direction comes from the Office of Manned Space Flight Programs, directed by D. Brainerd Holmes, NASA Headquarters. Responsibility for development and procurement of the launch vehicles lies with the Marshall Space Flight Center at Huntsville, Alabama, while the responsibility for development of the spacecraft and the conduct of the flight mission lies with the Manned Spacecraft Center, located at Houston, Texas. Thus, responsibility for hardware procurement for the spacecraft and the launch vehicle comes from Houston and Huntsville, respectively. The responsibility for integration of the spacecraft with the launch vehicle and the checkout of the integrated space vehicle lies within the Office of Manned Space Flight Programs. This activity is the responsibility of the Director of Integration and Checkout. Systems Engineering is also carried out within the Office of Manned Space Flight Programs. It is the responsibility of the Systems Engineering group to conduct overall mission and systems studies and recommend the mission guidelines by which the hardware elements will be developed for the conduct of the missions. In the Integration and Checkout area, the General Electric Company provides contractual support to the Director of Integration and Checkout, whereas in the Systems Engineering area, a new subsidiary of the American Telephone and Telegraph Corporation provides support to the Manned Space Flight Systems Engineering effort.

#### CONCLUDING REMARKS

It has not been possible in this brief paper to detail the great difficulties that lie ahead in developing these many pieces of complex hardware. However, at this point, it is appropriate to dwell on perhaps the single most important problem that lies ahead which is not the basic development of the systems required to do the job but the assurance of a system of adequate reliability for the overall accomplishment of the mission in an acceptable manner both from the confidence for success aspect and from a human safety aspect. If a reliability per stage or module of, say, 85 percent, which is perhaps a reasonably good figure today, is projected to the eight or ten stages or modules that are involved in the lunar-landing operation by means of earth rendezvous, a probability of mission success of 25 percent is obtained. Obviously, this is not an acceptable value. It is important to note that this does not represent the probability of safety, which would be a much higher value and would depend only on the reliability of the abort propulsion. In Project Apollo, a goal of 90 percent for probability of mission success has been set. With eight to ten modules or stages in the overall operation, a per-stage reliability of between 98 and 99 percent is required. Certainly, by today's standards, this is a lofty goal. It will require the best from all contributors in striving to attain that

goal. It will require sound design, judicious use of redundancy to obtain fail-safe and backup capability in critical areas, and excellent quality throughout the construction of the many systems involved. The task ahead in meeting these goals is overwhelming, and certainly the risks in conducting the program are great. The President, however, in committing the nation to this great program, did so in full recognition of the risks and hazards ahead and in the belief that the risk would be far greater if we do not undertake this program than if we do. The risk, of course, in not undertaking the program would be that this nation's capability in the areas of advanced research and development would decay and decline in comparison with that of those nations who do undertake the challenge. Certainly, the American way of life would not be compatible with the choice of the easy approach - that of failing to compete in this greatest engineering endeavor of all time.

## THE PROGRAM

- MERCURY-3 ORBITS
- 1 DAY MANNED MISSIONS
- PROJECT GEMINI
- PROJECT APOLLO
  - EARTH ORBITAL
  - CIRCUMLUNAR
  - LUNAR LANDING

Figure 1

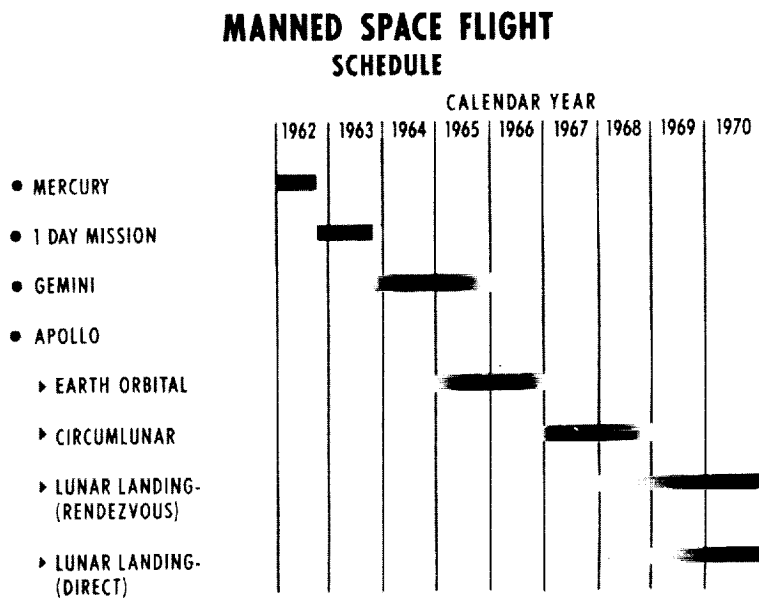


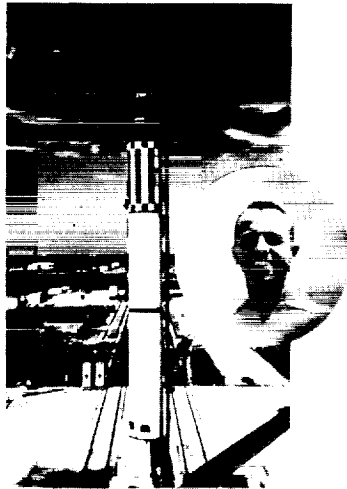
Figure 2

## PROJECT MERCURY FLIGHT TEST RESULTS

DATE	DESIGNATION	MISSION OBJECTIVES	
		ACCOMPLISHED	NOT ACCOMPLISHED
SEPT 9, 1959	ATLAS-BIG JOE	✓	
OCT 4, 1959	LITTLE JOE 1	✓	
NOV 4, 1959	LITTLE JOE 2	PARTIALLY	
DEC 4, 1959	LITTLE JOE 3	✓	
JAN 21, 1960	LITTLE JOE 4	✓	
JULY 29, 1960	ATLAS 1		✓
NOV 8, 1960	LITTLE JOE 5		✓
DEC 19, 1960	REDSTONE 1	✓	
JAN 31, 1961	REDSTONE 2	✓	
FEB 21, 1961	ATLAS 2	✓	
MAR 18, 1961	LITTLE JOE 6	PARTIALLY	
MAR 24, 1961	REDSTONE TEST	✓	
APRIL 25, 1961	ATLAS 3		✓
APRIL 28, 1961	LITTLE JOE 7	✓	
MAY 5, 1961	REDSTONE 3	✓	
JULY 21, 1961	REDSTONE 4	✓	
SEPT 13, 1961	ATLAS 4	✓	
NOV 29, 1961	ATLAS 5	✓	
FEB 20, 1962	ATLAS 6	✓	

Figure 3

## PROJECT MERCURY



### 1ST. U.S. MANNED FLIGHT

DATE: MAY 5, 1961

PILOT: ALAN B. SHEPARD

SPACECRAFT: FREEDOM 7

LAUNCH VEHICLE: REDSTONE

MAX. ALTITUDE: 116 MILES

RANGE: 302 MILES

WEIGHTLESSNESS: 5 MIN.

MAX. SPEED: 5180 MPH

Figure 4

## PROJECT MERCURY



### 2ND U.S. MANNED FLIGHT

DATE: JULY 21, 1961

PILOT: VIRGIL I. GRISSOM

SPACECRAFT: LIBERTY BELL 7

LAUNCH VEHICLE: REDSTONE

MAX. ALTITUDE: 118 MILES

RANGE: 302 MILES

WEIGHTLESSNESS: 5 MIN.

MAX. SPEED: 5220 MPH

Figure 5

## PROJECT MERCURY



### 2 ORBIT PRIMATE FLIGHT

DATE: NOV. 29, 1961

PRIMATE: "ENOS"

SPACECRAFT: MERCURY 9

LAUNCH VEHICLE: ATLAS

PERIGEE: 99.6 MILES

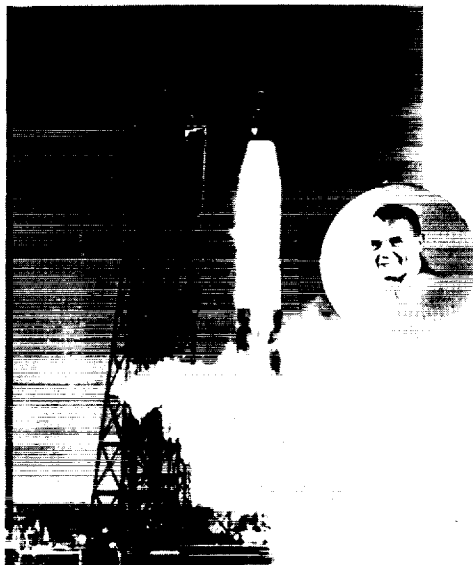
APOGEE: 147.5 MILES

WEIGHTLESSNESS: 3 HRS.

AVG SPEED: 17,500 MPH

Figure 6

## PROJECT MERCURY



1ST. U.S. MAN IN ORBIT

DATE: FEBRUARY 20, 1962

PILOT: JOHN H. GLENN, JR

SPACECRAFT: FRIENDSHIP 7

LAUNCH VEHICLE: ATLAS

APOGEE: 163 MILES

PERIGEE: 100 MILES

PERIOD: 88 MINUTES

ORBITS: 3

WEIGHTLESSNESS: 4½ HOURS

AVG. SPEED: 17,500 MPH

Figure 7



## 1-DAY MANNED FLIGHT

- EXTENSION OF OPERATING TIME
- ZERO GRAVITY EXPERIENCE

Figure 8

## PROJECT GEMINI

### OBJECTIVES:

- TO PROVIDE EARLY MANNED RENDEZVOUS CAPABILITY
  - DEVELOP TECHNIQUES
  - ASSESS PILOT FUNCTIONS
  - DEVELOP PROPULSION, GUIDANCE AND CONTROL
  - DEVELOP PILOT DISPLAYS
  - TRAIN PILOTS
- TO PROVIDE LONG DURATION MANNED FLIGHT EXPERIENCE
  - STUDY EFFECTS OF WEIGHTLESSNESS
  - DETERMINE PHYSIOLOGICAL REACTIONS
  - DETERMINE PSYCHOLOGICAL REACTIONS
  - DEVELOP PERFORMANCE CAPABILITIES OF THE CREW

Figure 9

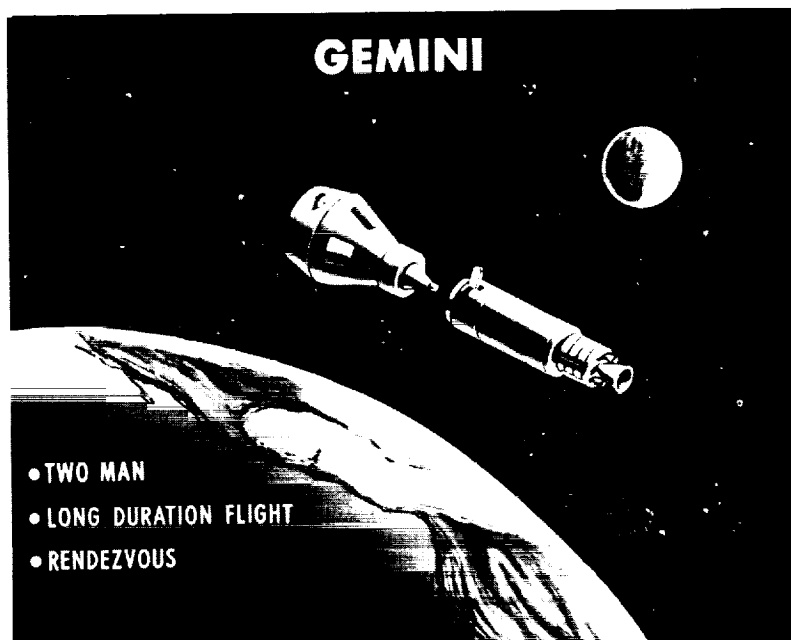


Figure 10

## PROJECT GEMINI LAUNCH VEHICLES

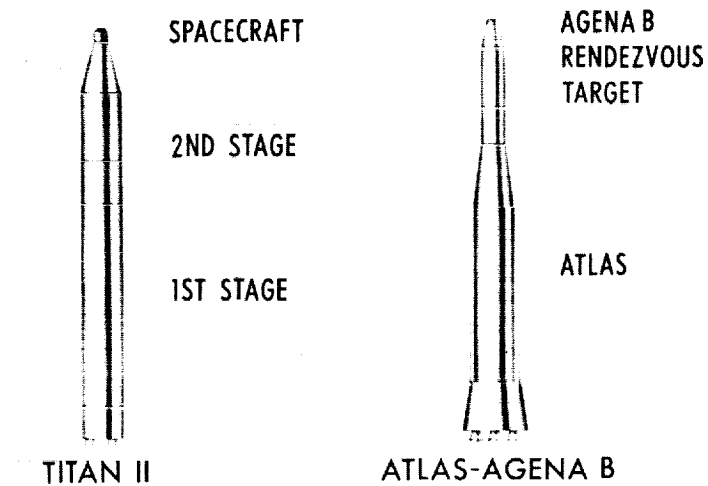


Figure 11

## PROJECT GEMINI FLIGHT MISSION

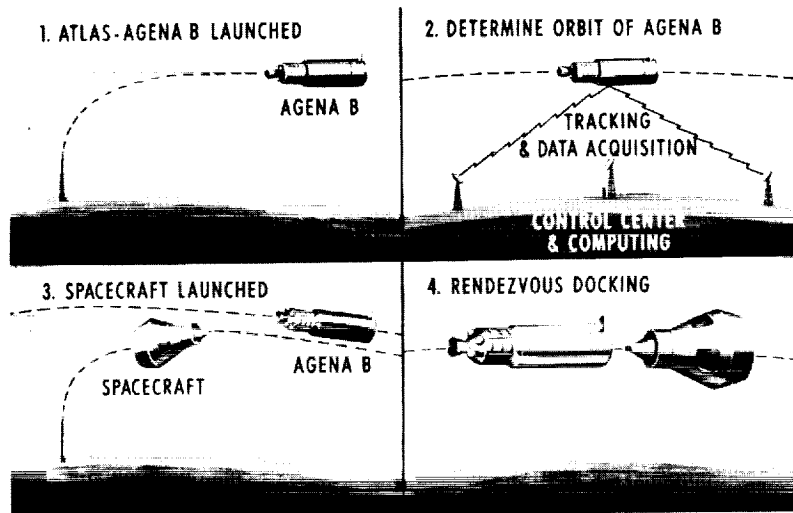


Figure 12

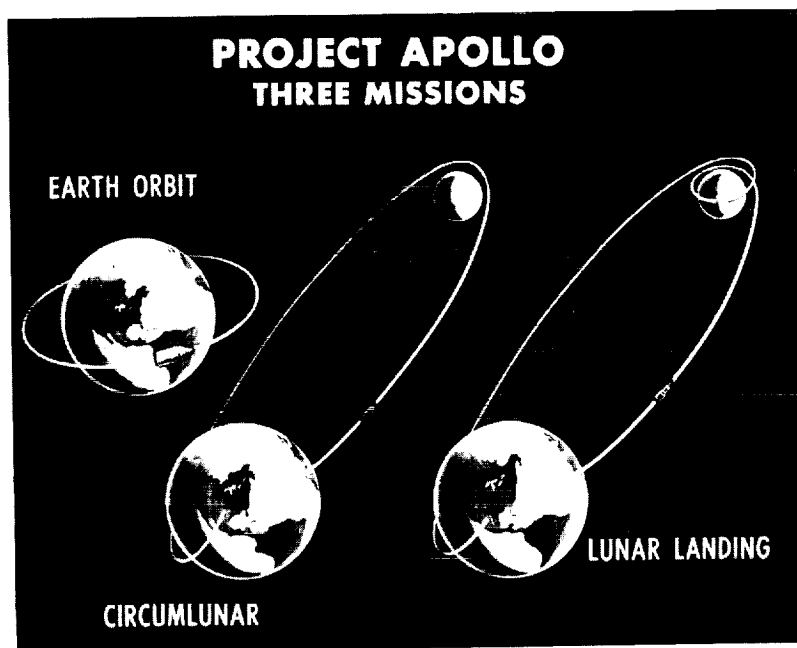


Figure 13

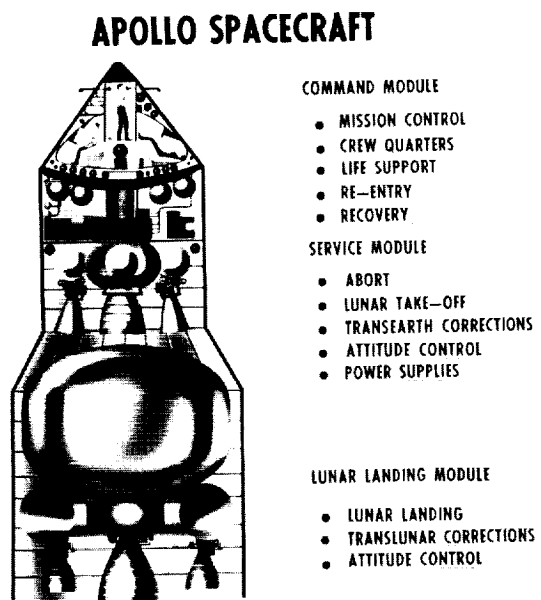


Figure 14

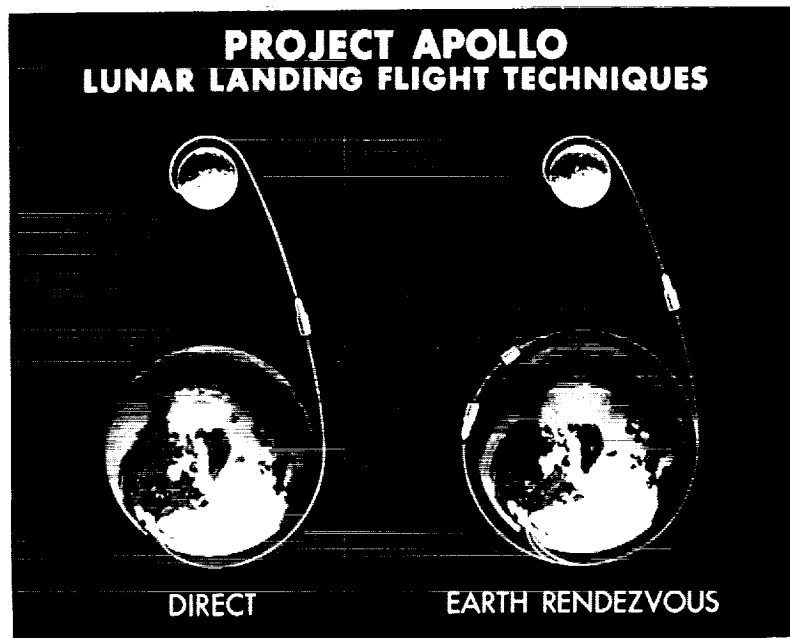


Figure 15

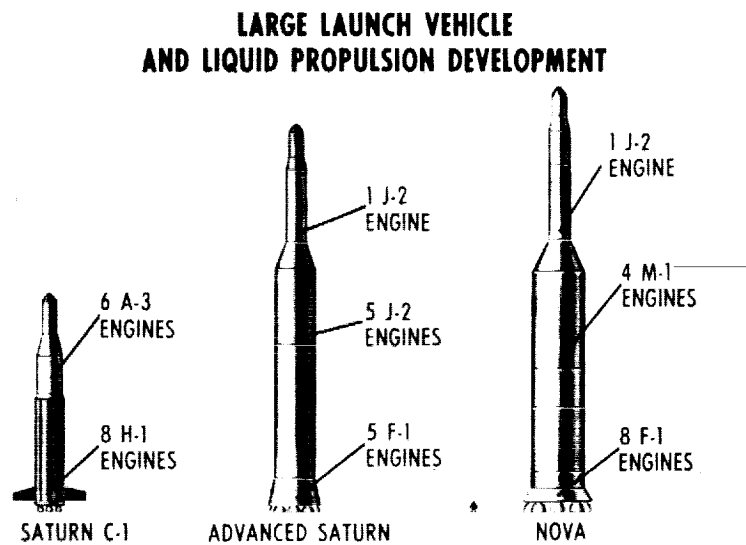
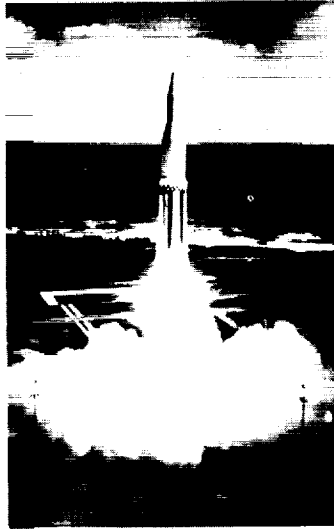


Figure 16



## FIRST SATURN LAUNCH



DATE: OCT. 27, 1961  
 VEHICLE: SATURN C-1  
 1ST STAGE:  
 8 H-1 ENGINES  
 TOTAL THRUST 1,320,000 LBS.  
 OXYGEN/KEROSENE  
 2ND AND 3RD STAGES:  
 INERT (WATER BALLAST)  
 LAUNCH WEIGHT: 920,000 LBS  
 MAX VELOCITY: 3,607 MPH  
 APOGEE: 85 MILES  
 RANGE: 215 MILES

Figure 17

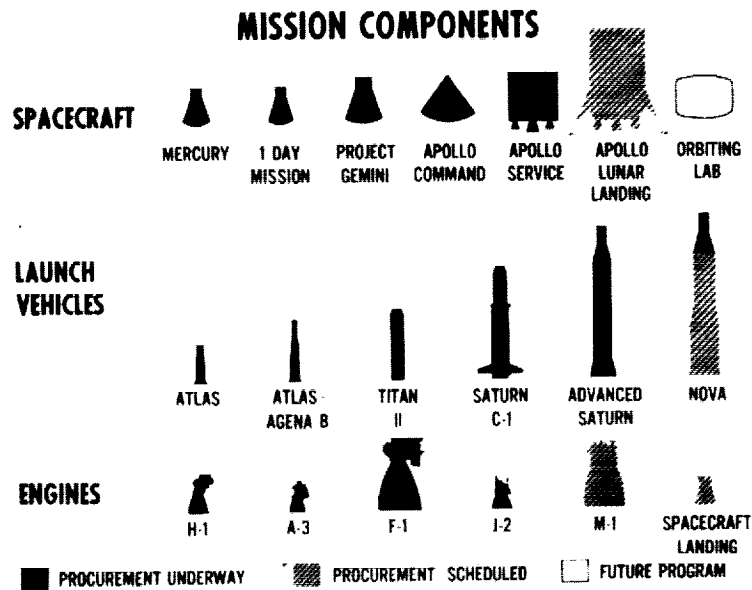


Figure 18

## NASA REQUIREMENTS FOR RELIABILITY AND QUALITY ASSURANCE

By Dr. Landis S. Gephart

A candid and lucid description of some of the more significant projects and activities which are encompassed in the broad based scientific program of the National Aeronautics and Space Administration has been given in the preceding paper. Special emphasis has been given to the NASA manned space activities, and rightfully so, I think, for therein lies one of the greatest technological challenges this nation has freely assumed as a matter of national policy. In this paper an attempt is made to place in proper perspective the signal importance of reliability and quality to the fulfillment of the mission of the United States in space.

The problem will be approached in two ways. However, it should be emphasized first that these two approaches will not be, classically, (1) reliability and (2) quality assurance. At NASA the classical definitions of reliability and quality assurance encompass a set of functions and responsibilities which are believed to be complementary. This is especially true in the research and development phases of a program, and practically all the NASA programs can be so categorized. Although, to date, NASA has retained the classical terms "reliability" and "quality assurance," the functions have been combined within one office.

One other point: The views stated in this paper represent the views of the NASA and deal with the actual requirements of NASA as an agency of the Government. As Dr. Robert C. Seamans, Jr., NASA Associate Administrator, stated in a recent speech on reliability, "I would like to talk about reliability in our space program as a matter of major national concern." In published statements, James E. Webb, NASA Administrator, and D. Brainerd Holmes, Director, Office of Manned Space Flight, have each emphasized the key role of reliability and of quality in the success of the NASA program. It is not a fad nor, for that matter, have reliability and quality gone unrecognized in the past. However, never in the past has reliability been so critical to our national programs.

In the development of this country's missile capability, trade-offs were always available. In theory at least, reliability could be optimized when the various factors such as cost, time schedules, number of missiles to be deployed under given conditions, warhead size, and so forth were properly considered. In contrast to this situation look ahead to a launch a few years hence - a launch of one of the major systems presently under development. This one launch may well cost over \$50 million, there may be three men in the spacecraft atop this

multistage launch vehicle, and their flight may last weeks rather than hours. That great event will be no time to find that the reliability and quality requirements have been inadequate. As someone recently said, "When you have a malfunction in space, you can't pull into Sammy's garage." No less critical is the need for reliability in unmanned vehicles, communication and weather satellites, orbiting observatories, and other spacecraft which will be expected to provide exact information over long periods of time. I think it is an undeniable fact that reliability in space systems is a national objective.

It should also be emphasized that reliability is not an attribute which can be treated separately in the system's design. It is, in fact, an integral part of good systems engineering, and the cost of the efforts to attain reliability of space mission equipment is inseparable from that of the engineering effort as a whole. Thus, responsible approaches to reliability must be inherent in both the project and its management, and must pervade every effort contributing to the project.

The chronology of the procedure by which reliability and quality requirements become integrated in the plan for a system's development and, within this procedure, the minimum set of requirements which must be carefully and deliberately considered are as follows.

The NASA program for reliability begins, as it must, at the procurement stage. The initial step in assuring reliability of major systems, therefore, is to incorporate into the NASA system-procurement plan the basic elements of the NASA reliability program policy, which are:

(1) The system shall have a desired minimum overall design reliability goal with a description of expected environments as detailed as possible, mission characteristics, and time period(s) associated with it.

(2) Since the inherent reliability is established by the basic design, a detailed analysis of the system, wherever practicable, should be performed at initial stages of design to guide the choice of acceptable trade-offs in performance, weight, and space. These endeavors will lead to a better knowledge of the system, may reveal weak design details of subsystems, components and parts, and thus will, through changes of design, improve the reliability toward the desired goal.

(3) Continuing analyses of system reliability shall be performed at appropriate steps of design, development, production, testing, and operational phases to evaluate the success in meeting the goal.

(4) A testing program shall be established for demonstrating, insofar as practical, that the system reliability can be achieved. Such

a test program must include the detailed test procedures and specific criteria for passing or failing the tests with the associated probabilities, as feasible.

In implementing these policy elements, the NASA procurement plan also provides that requests for proposals for major systems will include reliability provisions to which the bidder will respond by indicating methods he proposes to use in demonstrating reliability achievement. Included among these provisions are:

(1) Analysis of the preliminary system design to establish reliability prediction of the system, if possible

(2) The procedures to be used for allocating the reliability requirements among the various subsystems, components, and parts comprising the system

(3) Test programs for determining failure rates of the critical parts of subsystems of the overall system

(4) Periodic analysis and monitoring of system reliability at subsequent steps of design, development, production, testing, and operational phases to evaluate the success in achieving the reliability goal; status reports of these analyses to be submitted to NASA

(5) A proposed program for demonstrating the overall reliability performance

(6) The reliability organization and activities to achieve overall control and coordination of the reliability efforts outlined above

In addition, the NASA procurement plan contains the recommended method for handling reliability assessment. In general, reliability assessment will be conducted by NASA field installations responsible for major systems. NASA may conduct this assessment on an in-house basis, or via contract, employing special reliability assessment contractors.

Thus far, the details of specific tools and/or procedures have not been discussed, nor has the NASA reliability policy specified a single set of techniques which a system's developer should use. There are several valid reasons why the latter is not done. First, the system's developer cannot be relieved of the responsibility for producing a system which meets its specified requirements. Furthermore, it is the intent of NASA to encourage continually the development of new and better techniques. In addition, it has been our experience that the appropriateness of techniques is not only associated with specific systems but is also greatly influenced by mission requirements.

When it is considered that today a single launch of a Saturn class vehicle will cost in excess of \$20 million, it can certainly be justified, and, in fact, required, that extensive effort be devoted to theoretical and analytical engineering studies in initial phases of a system design and development. Obviously, the same considerations must apply to the spacecraft which will be launched by such vehicles. Hence, much of the NASA reliability effort supports this emphasis on the planned analytical approach.

The other aspect of reliability is quality assurance. The official NASA policy on this has been released and provides, also, the careful controls needed to develop and produce system hardware with designated degrees of reliability.

In order to assure the desired quality of space systems, or parts thereof, responsibility has been established as follows:

(1) The Headquarters Office of Reliability and Quality Assurance is responsible for providing policy guidance and coordination of the NASA quality-assurance program.

(2) The Director of each field installation will establish a single organizational point for quality-assurance responsibility and authority in the installation.

(3) NASA installations shall retain overall responsibility for the quality of items and services procured and cannot delegate this responsibility. Within this continued responsibility, NASA installations may delegate authority for quality review activity to existing and available organizations.

The basic policy is expressed as follows:

(1) It shall be NASA policy to utilize every practical means of assuring high quality of space systems. In order to accomplish this objective, quality-assurance requirements shall be placed contractually on space system contractors and subcontractors by NASA installations.

(2) Assuring satisfactory contractor performance in developing and maintaining the quality of space systems and their parts is the responsibility of the cognizant installation, assisted by Government inspection agencies to the extent determined advantageous by the NASA installation.

The following quality-assurance program elements shall be incorporated as part of the overall reliability and quality-assurance program for each stage of space systems development:

(1) Quality-assurance characteristics and procedures will be planned, identified, and quantified.

(2) Means will be developed to:

(a) Demonstrate continuous conformance to standards for quality characteristics and procedures.

(b) Document and use quality information and data feedback to improve quality and prevent quality degradation.

(3) Quality information and techniques generated by NASA, industry, and other Government services will be disseminated, as appropriate, to NASA contractors and installations, so as to provide for the widest use of existing knowledge and for the development of new techniques.

Obviously, the essential policy of quality assurance provides for positive action to be taken as follows: NASA will implement the quality-assurance policy outline. Three new quality publications (refs. 1 to 3) have been developed which will provide a common framework to obtain the degree of quality assurance necessary for NASA space programs. Reference 1 is used by NASA field installations to transmit their quality-assurance requirements to an inspection agency delegated by NASA. NASA does not have its own inspection agency, although in certain special cases NASA may do its own inspection or perform those functions which, for whatever reasons, cannot be readily delegated to another agency. Reference 2 is addressed to major space-system contractors, and sets forth quality program procedures and requirements. Reference 3 sets forth minimal requirements for parts and components which might well be invoked in "small business" type of procurements by NASA installations or by systems prime contractors.

These three publications are, in my opinion, as truly representative of NASA requirements as can be set forth in a general type of document. Since NASA had no precedent in this field, they were arrived at in several stages by a cooperative endeavor of the NASA Centers, with subsequent reviews by the Aerospace and Electronic Industries Associations, and the Army, Navy, and Air Force, which followed up with official letters of approval concerning inspection agency responsibility.

In addition to those reviews, and concurrent with the last one, a third and very important review was also conducted by a Quality Review Board under the chairmanship of Major General Leslie E. Simon, a pioneer in quality-assurance programs undertaken by both Government and industry. This Board critically studied the drafts of the three NASA quality publications and gave advice with regard to three important areas:

- (1) Technical content
- (2) Management implications, with respect to both NASA and its contractors
- (3) Interrelations between NASA and any other Government agency, particularly the Army, Navy, and Air Force

These publications are consistent with Department of Defense quality-assurance policies and key specifications and provide for significantly higher quality products and for the far-more-detailed control procedures applicable to the research-and-development nature of NASA procurements. The following excerpt from the final report of the Quality Review Board may give a better appreciation of the importance and potential impact of these publications in NASA space-system procurements:

On the subject "The Need for Upgrading Quality," the Board stated "It should be observed that just as more rigorous quality programs were necessary to achieve satisfactory quality in guided missiles, a similar upgrading of quality over and above that currently associated with guided missiles is not only necessary to economy in space vehicles (because of their much greater unit cost) but is also necessary to their expeditious development, to their inherent performance capability, and to the safety of personnel.

"In addition, the NASA documents have the potential for helping to decrease both the time required for and the cost of the development of missiles because many of the measures (but not all) stated for space systems are applicable with little or no alteration to missiles. The NASA documents have been coordinated with the three military services."

On the subject "The Size of the Program," comments of the Board were as follows: "In application, the documents will require both a large increase in inspectors and quality-assurance personnel of high grade as well as a substantial upgrading of people engaged in this work. Due to the increased inspection personnel and other associated causes, the unit cost of space vehicles may well be increased quite substantially. Just as the introduction of "Reliability" into the Nike program (circa 1952) introduced repercussions extending even to college courses in the subject, so are the NASA documents a design for a further increase of a whole order in quality and will result in concomitant changes in philosophy, engineering techniques, numbers of technical persons, and unit costs.

"It should be made clear at the outset," the comment concluded, "that this is a big, big program. Nevertheless, the cost per space program should be reduced, because space programs tend to consist of

perhaps six vehicles in a series of a kind. The saving of only one or a few aborts in a series would probably more than offset the increased expense - to say nothing of the catastrophic failure of all vehicles in a program, which is not a remote probability under ordinary quality-assurance procedures. NASA failures will be subject to close public scrutiny, both at home and abroad; and wholesale failure of space vehicles might be tantamount to national disgrace."

It seems clear that the Quality Review Board did not intend that these words of caution should be interpreted as reflecting pessimism, but rather that it is their belief that to be forewarned is to be forearmed.

We certainly realize that it is not the existence of policies or procedures or publications which really get a job done. Rather, it is diligent application with meticulous attention to detail by both Government and industry that will help to achieve the order of reliability needed to accomplish the most difficult mission. If major improvements in reliability are to be achieved, it is obviously necessary to fire the zeal of every member of a development team, of every participant in an industrial process or launch operation, to do the job right. In preparing for a space mission, there is no substitute for inspired enthusiasm geared to persistent attention to detail.

This paper has stressed the demand for high reliability and high quality products to meet the challenge of the space age. In no sense would I detract from the stark realism of these requirements. But I would reflect for a moment on the truism that if the challenge of the space age can bring to this nation a more fervent desire to do the job right, and to take pride in so doing it, that in itself may well be one of the major benefits to be derived from our efforts.

As Dr. Seamans recently stated, "We are engaged in a tremendous scientific and technological effort to carry out our accelerated national program. After the brains, the skills, and the industrial resources have been marshalled, the key to success still lies in reliability - the assurance that men and equipment will do what they are supposed to do at the right time and for the right period of time, in every phase of long and complicated operations."

## REFERENCES

1. Anon.: Quality Assurance Provisions for Inspection Agencies. NASA Quality Pub. 200-1, Mar. 1, 1962.
2. Anon.: Quality Program Provisions for Space System. NASA Quality Pub. 200-2, Mar. 1, 1962.
3. Anon.: Inspection System Provisions for Suppliers of Space Materials, Parts, Components, and Services. NASA Quality Pub. 200-3, Mar. 1, 1962.

## NASA PROCUREMENT POLICIES

By Ernest W. Brackett

The preceding discussion of the NASA program may have stimulated the following questions: How much of the NASA program will be accomplished by contracts? how can a particular company arrange a contract? and what is the Procurement system of the NASA?

Since the contracting is done mainly by the NASA research centers and installations, it may first be helpful to describe them and the particular interests of each.

Some companies may have done business in years past with the National Advisory Committee for Aeronautics (NACA) at its aeronautical laboratories which consisted of Langley, at Langley Station, Hampton, Virginia, Ames at Moffett Field near San Francisco, California, and Lewis at Cleveland, Ohio. All of these became a part of the National Aeronautics and Space Administration.

Since NASA came into being, the Jet Propulsion Laboratory at Pasadena, California, which is operated for NASA by the California Institute of Technology under a contract, and the technical group under the direction of Dr. Wernher von Braun with the facilities they were using at Huntsville, Alabama, now known as the George C. Marshall Space Flight Center, were transferred to NASA. Two new centers are being built, the Goddard Space Flight Center at Greenbelt, Maryland, and the Manned Spacecraft Center at Houston, Texas. Also, the Wallops Station at Wallops Island, Virginia, the NASA Flight Research Center at Edwards Air Force Base, California, and the Western Operations Office at Santa Monica, California, are NASA installations and also do contracting. There is a small contracting office at the NASA Washington headquarters which contracts for projects monitored by the headquarters' staff.

A booklet entitled "Selling to NASA" which has the addresses of all these NASA organizations and some information about what they purchase has been compiled. Copies of this booklet are available. I would suggest that any company interested in selling products or services to NASA file a Standard Form 129 with each of the offices with which it wishes to do business.

The NASA is under the same legal procurement authority as are the military departments, the Armed Services Procurement Act of 1947. Many of the items bought by the NASA are similar to those produced for the Army, Navy, and Air Force, and many of the companies whose services will be sought have been and are largely engaged in providing items for the military. Much of the NASA research and development contracting will be done with the aeronautical, electronic, ground support, and

construction industries which have been the bulwark for the military research and development programs. Many of the contractors in these fields have extensive facilities available for producing and testing items which would cost millions of dollars to duplicate. Therefore, in the interest of simplicity and economy, NASA follows closely the procurement procedures and contract provisions which the military departments have developed and perfected over a period of years and with which contractors in these fields are familiar.

Technically, NASA is under the Federal Procurement Regulations issued by the General Services Administration. The NASA implementing procedures are published in the Federal Register and, for internal use, are part of the NASA Management Manual. The NASA implementing instructions follow closely many of the policies and procedures found in the Armed Services Procurement Regulations (ASPR); for instance, the contract cost principles, which include allowable costs, are the same as those found in Section XV of ASPR.

Most of the larger NASA contracts are for research and development, in such areas as the design and development of large engines, space vehicles, and satellites, where the cost is very uncertain. The type of contract best suited for such procurements is the cost-plus-fixed-fee contract. Of course, construction work, supplies, and everything possible are bought through formal advertising.

An attempt is being made to find ways of putting incentive provisions into NASA research contracts. In an effort to encourage contractors to reduce costs and produce items with the optimum of performance, the NASA is willing to pay higher-than-usual fees with a reduction in fee if costs go up or performance is not good. The key to incentive-type contracts is being able to fix fair target costs or performance targets; however, where an item has never been produced before, such as the Apollo spacecraft or the Relay communication satellite, this is difficult.

Each year some construction contracts are made. For the most part NASA does its own contracting for construction work; however, in certain instances it may ask the Corps of Engineers or the Bureau of Yards and Docks to do this. The Corps of Engineers is now doing the construction contracting and supervision at Houston, Texas. The NASA first selects an architect-engineer who draws the plans and specifications. The A-E contractor is chosen by a board at the Center requesting the contract which reviews the qualifications of A-E firms and selects the company considered to be best qualified. Because architectural engineering is a profession, price competition for business of this type cannot be held.

After a contract has been negotiated and signed, it has to be administered during performance. In most instances, the military department that has cognizance of the plant where the work will be done has been asked to administer the contract for NASA. This includes sub-contract approval, overtime approval, auditing, recommendation of vouchers for payment, in some instances quality-control inspection, and other contract administration function. This service that the military departments are rendering is greatly appreciated, and it saves the Government the cost of setting up a duplicate staff; contractors also have the advantage of finding only one system to follow.

Any dispute which arises under the Disputes Clause is referred to an NASA Board of Contract Appeals rather than the Armed Services Board. Also, any change in the contract under the Changes Clause is negotiated and written by the NASA Contracting Officer. However, NASA may ask the military department to analyze a contractor's proposed costs, both for a change in an existing contract or for a new procurement, and NASA also may ask a military department for advice as to a contractor's capability. NASA does not have disbursing finance offices as does the military. When a voucher is in order for payment, it is approved by an NASA certifying officer and sent to the Treasury Department for payment. NASA has its own Contract Adjustment Board which considers claims filed by contractors for extraordinary relief. It also has received authority from the Comptroller General to pass on mistakes in bids alleged by bidders under formally advertised procurements.

At times, one of the military departments, or another Government agency, is requested to buy an item for NASA since the other department or agency is buying the same or similar items. That department buys for NASA through its own contracts. It selects the source and it negotiates and signs the contract using its own clauses with the exception of patent clauses. NASA transfers funds to the Purchasing Department to pay the cost of the contract, and the NASA technical staff may have a part in the technical direction of the contract.

NASA is a participant in the Department of Defense Industrial Security Program. If an NASA contract involves classified information - and some do - the contractor must be cleared by one of the military services for access to classified information in the same manner as though a Department of Defense contract in which classified information is included were involved.

If the NASA contract is classified, a standard clause in the contract requires the contractor to execute a Department of Defense security agreement if the contractor has not already done so. The same security rules then apply and the same security clearances are applicable as though it were a classified contract with one of the military services.

If the contractor does not possess a Department of Defense clearance, NASA will arrange for the necessary security inspection and clearance by one of the military services. This arrangement between NASA and the Department of Defense not only avoids duplication in granting of clearances and making security inspections but should benefit industry by avoiding conflicting or duplicating security requirements for the contractor.

NASA contracts carry a priority rating. The Mercury and Saturn projects have a DX rating, the highest priority assigned. The other contracts carry a DO rating, which entitles contractors to secure materials ahead of regular production. There appears to be no program requirement for production-type contracts in the foreseeable future from NASA. The procurement field, at least for some time to come, is research and development. NASA has thus far not adopted the so-called systems management by contractor concept; however, it may be adopted in an individual program where it is necessary to place full responsibility on one contractor to integrate a complete project.

The patent provisions in NASA contracts are of some concern to industry because they depart somewhat from the pattern set in military contracts. In military research and development contracts there is a clause which provides that the contractor, if he makes a patentable invention during performance, may secure and own a patent on the invention. He may exploit it commercially and charge royalties on it. However, the contractor must grant to the Government a royalty-free license so that the Government may buy the item from that company or from any other company or may produce the item without paying a royalty. The Space Act provides for a different procedure which NASA must follow in its contracts. If the Administrator makes certain determinations of fact concerning the conditions under which the invention is made during performance of an NASA contract, the invention becomes the property of the United States. This does not mean, however, that the Government will attempt to take title to inventions which a contractor had patented before performance of the NASA contract. However, under certain conditions the Administrator may issue a waiver of taking title, or he may license a company or companies to use the inventions after they are patented. The Administrator will not waive rights to inventions in advance of performance of the contract. When another department, for instance the Air Force, buys an item for NASA, the NASA patent provisions must be included in that contract because the patent restrictions follow the use of NASA funds.

Industry generally feels that the patent provisions of the Space Act take away one of the incentives to taking a Government research and development contract because it sees less opportunity to use commercial inventions made during performance. On the other hand, some interests feel that any invention which is made during performance of a contract

paid for by Government funds should be equally available to all companies, or at least not be the exclusive commercial property of the inventor contractor. It is suggested that any company having special questions on the NASA patent position, which is basically a matter of statute rather than policy, contact the NASA Assistant General Counsel for Patent Matters.

What does NASA buy? As previously mentioned, NASA has seven research centers and each of these does a certain amount of research work within its laboratories. These are large installations with wind tunnels, test equipment, and similar facilities. The Ames Research Center is the largest single customer for electric power in California. These centers buy their own equipment and the supplies they use. Compressors, valves, tubing, all kinds of tools, and equipment are purchased there. The Marshall Space Flight Center carries about 50,000 line items in stock and only about 35 percent of the items it uses comes from this stock, the balance being purchased as the need arises.

The Marshall Center has been developing the first stage of the Saturn space vehicle although the limited production of these will be done later by contract. The development of engines for space vehicles is a Marshall project. The Langley Research Center specializes in research in aerodynamics problems. It is studying aircraft vertical take-off and landing. Lewis Research Center does research on propulsion, power generation, and new types of fuel. It has a large atomic reactor under its control and is studying cryogenics. The Goddard Space Flight Center specializes in space satellites, sounding rockets, and communication systems. When Astronaut Glenn was orbiting the earth he carried on a constant conversation by means of a large communication center at Goddard which picked up his voice at seventeen different stations around the world. Ames Research Center specializes in high-speed aerodynamics and does both basic and applied research in aeronautical and space flight problems. The Manned Spacecraft Center has as its large project the Apollo three-man spacecraft program.

In addition to the in-house research work, these Centers contract for research and development of the projects that are assigned to each. This is where the largest amount of the NASA budget is spent. Last year, approximately 84 percent of the total NASA budget was spent on contracts and this next year it is anticipated that this percentage will go up to 90 percent. Thus, it is evident that there is no plan to increase work within the centers appreciably but rather to rely on contractors for development of the NASA program. The total request for funds for NASA which Congress is now considering is approximately \$3,748 million. The amount which the Congress will appropriate will be available for the 1963 fiscal year which starts July 1, 1962.

The projects and items planned for procurement during the next fiscal year are outlined in the reports of the hearings before the appropriate authorization committees of the House of Representatives or Senate Committee on the NASA Authorization bill. This is an excellent way to estimate in advance what may be bought and to find out estimates of costs and what Center will handle the procurements. It is then possible to follow particular projects at the Centers. Some contracts run for several years; for instance, the development of the large F-1 engine which will have 1,500,000 pounds of thrust will take 4 years or more to complete. Funds may be appropriated for only 1 year at a time. This is known as incremental funding and NASA contracts which are so funded have a special provision which limits a contractor's work to the extent of the funds then obligated on the contract.

The most difficult part of procurement, I believe, is choosing contractors for research and development contracts. Where a space vehicle or satellite or engine for space travel has never been made before, and thus no specification but only a conceptual design exists, where the costs of such a development can only be estimated, and where several or sometimes many companies want the contract, selection of a contractor is a big problem.

A source-selection procedure has been developed at NASA and is presently being used. When a research and development procurement estimated to cost \$5,000,000 or more is planned, Dr. Robert C. Seamans, the Associate Administrator, appoints a board before the procurement is started which will evaluate company proposals. This board decides what points or criteria it considers should be the basis for evaluation and these are written into the Request for Proposal so that companies will know what to cover in drafting their proposals.

Companies are usually invited to a preproposal conference where the subject of the procurement is outlined and they are given the opportunity to ask questions. Although competition is not limited, only those companies which are considered to have the experience, technical staffs, and facilities to do the work successfully are encouraged to enter proposals. The fact that a company elects not to submit a proposal for a certain item does not count against it in future procurements.

After proposals are received, the evaluation board gives them thorough and careful review. Although cost is an important element, the technical part of proposals is considered the most important factor. Also, the board looks for such things as what experience a company has had in similar work, what staff it will assign to the project, what importance it will have in the company's organization, and what facilities and plant capacity it has available. It may also check with the

military departments to see what their experience has been with the companies entering proposals. Questions may be asked such as: Have they produced on time? do they usually overrun estimated costs? are they cooperative? and have the items they developed performed satisfactorily?

After completing its evaluation the board reports to the Administrator and key members of his staff, and then the Administrator, Mr. James E. Webb, his deputy, Dr. Hugh L. Dryden, and the Associate Administrator, Dr. Seamans, select the company with which the NASA will negotiate a contract if satisfactory terms can be reached. The purpose of this procedure is to give all interested companies a fair and equal chance for a contract and to select the company which affords the best possibility of successfully performing the work. The work of preparing proposals is expensive and requires the time of top engineering personnel. New methods of contractor selection are being studied to simplify the procedure and any suggestions will be appreciated.

There are occasions when it is evident that one company, because of certain factors such as its predominance in a field or its specialized experience, is clearly the company which should be the contractor for an item of work. It would be a disservice to other companies to ask for competitive proposals. However, such occasions are by far the exception and the basic rule is to solicit competition whenever possible.

When a cost-type contract is placed with a contractor, the NASA is, in part, buying the management of that company in supervising the expenditure of Government funds. The contractor is expected to be just as careful in how money is spent in performing NASA contracts as he would be in spending company money to produce a commercial item for profit.

The NASA is concerned about cost overruns, where the ultimate cost exceeds the original estimate. Sometimes, a low estimate is interpreted as meaning a lack of concept by the company of what the work really entails. Cost overruns may mean that the contractor has not done a good engineering job which has caused costs to go up, or that there has been a lack of planning and proper cost estimating. Confidence in a company is lowered when the ultimate cost of a project far exceeds its estimate.

NASA is considering a system of contractor performance evaluation, a method by which companies can be rated as to whether they are doing a good or poor job and, at the completion of performance, told how they rated. Did a company meet its delivery schedules, did it keep within reasonable cost estimates, did the delivered item perform as it was supposed to, was its reliability good, and did management cooperate are factors which will be considered. Future contracts with a company may

depend to a large extent on the answers to those questions which will become a matter of record.

What is NASA doing for small business? Some NASA contracts are for engines, satellites, space vehicles, and items which require companies having large facilities, engineering staffs, and extensive experience in a field. To duplicate the facilities alone would cost many millions of dollars which NASA cannot afford. This type of contract must usually go to a large business concern. However, there are many contracts which are within the capability of small business companies and an attempt will be made to see that small business companies receive a fair share of NASA business. Out of the 100 largest contracts NASA placed during the first 6 months of the present fiscal year, small business companies received 21. However, prime contracts are not the sole channel of dollars into the hands of business concerns; subcontracts also provide business dollars and it is in the subcontract area that I believe small business has the greatest possibility of sharing in the NASA program. Recently there was occasion to look into the subcontract spread of one of the largest NASA prime contracts. It was found that there were over 900 first-tier subcontracts and, of these, over 700 went to small business concerns. Altogether, there were approximately 4,000 first-, second-, and third-tier subcontracts which were spread over 37 states and in 35 states small business concerns received subcontracts.

In the past, one of the difficulties smaller companies interested in subcontract work experienced was in learning where to go to sell their products or services. By the time the larger companies had submitted their proposals they had usually committed much of their subcontract work; thus, when the name of the successful company was announced, after a competition for a large prime contract, it was too late for smaller companies to participate.

In order to overcome this difficulty NASA now synthesizes in the news medium entitled "Synopsis of U.S. Government Proposed Procurement, Sales and Contract Awards," which is published each business day by the Department of Commerce, under the heading of subcontract opportunities, a list of all its proposed research and development contracts of \$100,000 or over. Not only is the subject of the contract work published but also a list of all the companies with their addresses to which the NASA is sending requests for proposals. It is published at the same time the requests for proposals are mailed out so that companies interested in subcontract work can contact these prospective prime contractors before their proposals are drawn. NASA, of course, publicly announces the name of the company selected as the prime contractor as soon as the selection is made.

When one of the larger contracts is negotiated, the prime contractor is required to submit a list of the parts or components planned for manufacture in his plant and those he intends to purchase by subcontract. Agreement on the list is a part of the contract negotiations and a clause is placed in the contract, known as the "make or buy" clause, which provides that before the contractor deviates from that list he must obtain permission from the contracting officer. The objective of this provision is to be sure that the contractor subcontracts to the greatest extent practical and economical. Many items can be subcontracted at less cost and with more efficiency than they can be produced by a contractor in his own plant.

In all NASA contracts over \$1,000,000, and also in subcontracts over that amount, there is a provision that the contractor must have a small business program. He must have a small business officer and must be certain that when subcontracts are placed competition is secured, if it is possible, and that small business concerns are given an opportunity to compete.

Each of the NASA Centers has a small business specialist who will be glad to advise any small business company. Mr. Jacob Roey, Industrial Assistant Advisor, is in charge of the small business program at NASA Headquarters and his counsel is available to anyone who wants it. During the first 6 months of this fiscal year the procurements set aside for small business participation increased 225 percent over those of the same period last year. Prime contract dollars which went to small business companies increased 39 percent over the amount last year, and although the dollar total of all contracts to large business is substantially more than that to small business concerns, 66 percent of the total number of contract actions went to small business. Thus, it is evident that the NASA does have an active small business program.

A company may have an idea or a product which it believes will be useful in the NASA program. In such a case a company may submit an unsolicited proposal for a contract. The proposal will be evaluated and, if it is considered to have merit and can be used and if there are funds for it, a contract may be placed for study or even development of the item. Unsolicited proposals should be addressed to the Director, Office of Research Grants and Contracts, Dr. Thomas L. K. Smull.

A constant effort is being made to improve the NASA procurement system and any suggestions will be appreciated. An attempt is being made to streamline contract procedures so that NASA contracts can be placed with a minimum of delay and formality. This does not mean that a less thorough procurement job will be done; an effort is made not to sacrifice the Government's interests for the sake of speed.

I would like to say just a word about the purpose of NASA and its program, what it means to industry, to our country, and to the world. The Space Act says, in part, "The Congress hereby declares that it is the policy of the United States that activities in space should be devoted to peaceful purposes for the benefit of all mankind." This is what the NASA program aims to do.

There are practical results which are almost certain to come in the foreseeable future. Within a few years you will be able to talk with London or Madrid by way of communication satellites and you will see television programs broadcast from Paris or Tokyo. Another benefit will be long-range and accurate weather predictions. There will also be new items of a commercial nature which will come about as byproducts of the research and development of this program.

This is a program that will have a tremendous effect on our standing as a nation. It is a program which other nations will understand to be for the benefit of mankind and our prestige as a nation may well be determined to a large extent on how well it is conducted. Some of the program will be spectacular, some of it will be purely scientific. There are bound to be delays and failures but ultimately thrilling successes.

The fact that NASA expects to spend 90 percent of its appropriations by way of contracts shows the part industry must play. Success will mean teamwork between the Government and industry, and procurement is one of the connecting links.